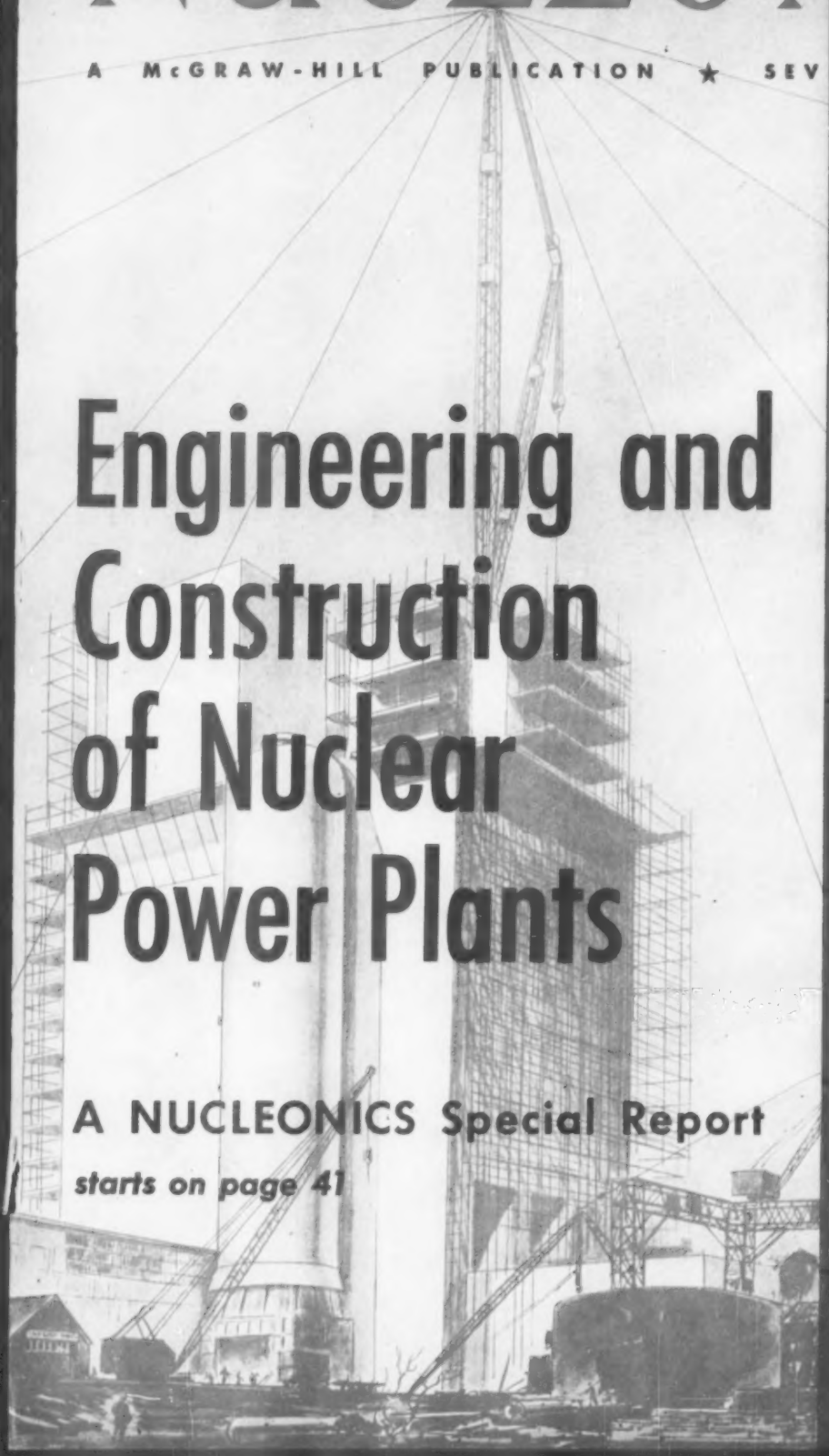
June 1958

NUCLEONICS

A McGRAW-HILL PUBLICATION ★ SEVENTY-FIVE CENTS



Engineering and Construction of Nuclear Power Plants

A NUCLEONICS Special Report

starts on page 41

1 Site Selection and Plant Layout

2 Water Supplies for Reactors

3 Control-Rod Mechanisms

4 How to Load Solid-Fuel Reactors

5 Designing and Building Shields

6 Reactor Vessels

7 Core Construction

How to measure your high-vacuum vapor pump's efficiency . . . *in pints, quarts, and gallons*

The fluid in your high-vacuum vapor pump helps determine how much work it will do—and how fast.

The ultimate pressure your pump will produce depends in large measure on the vapor pressure of the pump fluid.

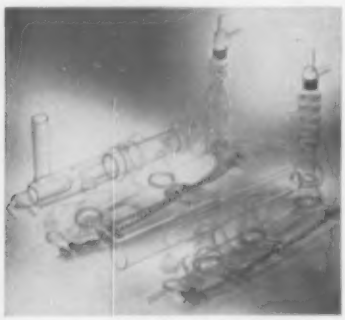
The chemical and thermal stability of the fluid largely determines the maximum throughput and limiting forepressure your pump achieves.

Still other characteristics affect ultimate pressure and the speed with which you reach it.

This is the reason *CVC* has developed the variety of vapor-pump fluids described below, to meet the needs of every type of vapor pump.

For further information on these fluids and how to select the one that's best for your pump, write to .... ***Consolidated Vacuum Corporation, Rochester 3, N.Y.*** (a subsidiary of ***Consolidated Engineering Corporation, Pasadena, California***).

RECOMMENDED VAPOR-PUMP FLUIDS



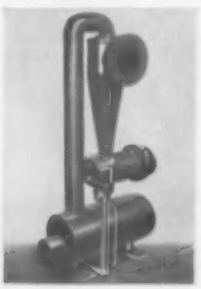
Octoil-S—*for glass fractionating pumps. Consistently gives pressures of 1 x 10^{-7}mm Hg or less. Unsurpassed for obtaining low ultimate pressures without a cold trap. CVC's type GF-25 pumps illustrated.*

Octoil—*for three-stage diffusion pumps. Works against higher limiting forepressures than Octoil-S. Produces low ultimate pressure of 10^{-6}mm Hg. CVC's type MCF-60 pump and port assembly illustrated.*

Convoil-10—*for high-boiler pressure pumps. Works against limiting forepressures as high as 5mm Hg. CVC's type KJ-5000 pump illustrated.*

Convaclor-12—*for diffusion-ejector pumps where gas loads range as high as 50,000 to 1,000,000 micron-liters per second. Gives greater throughput against high limiting forepressures than Convoil-20. CVC's type KS-4000 pumping system illustrated.*

Convaclor-8—*for diffusion, diffusion-ejector, and ejector pumps. Tolerates more heater input than most pump fluids with improvement in limiting forepressures without serious increase in ultimate pressures. CVC's type MB-200 pump illustrated.*



Convoil-20—*for larger fractionating pumps where an ultimate pressure of 8 x 10^{-6}mm Hg is sufficient; for oil-ejector pumps where pressures of 10^{-5}mm Hg are required against high limiting forepressures. CVC's type KB-150 pump illustrated.*

CVC

Headquarters for High Vacuum

Consolidated Vacuum Corporation

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NUCLEONICS

JUNE • 1955

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About NUCLEONICS

All eyes on Geneva. When we put together the story on the U. S. planning for the Geneva conference for the May NUCLEONICS, we were impressed and overwhelmed by the magnitude of the job involved in getting ready for the conference. But developing the facts for this month's article (p. 73) on the United Nations work on the meeting has convinced us that the largest assault on the peacetime atom is now under way.

Managing Editor Mosbacher who wrote the UN story (and the one in May) spent a number of days at the UN Secretariat building in New York and came up with this observation, "If you think the U. S. or any other nation has a problem, take a look at what the UN faces. They've got to deal with over 50 nations, make sure all are treated fairly on the program, come up with a good nonpolitical technical program, and do all of this in four working languages!"

From all reports, every atomic energy organization in the world—large and small—is in some way involved in the conference. A recent trip through western United States found most key people writing technical papers or lining up elaborate exhibits, such as working models of reactors. There's no doubt that the exhibits at Geneva will be the most elaborate ever produced in this field.

Another major activity right now is guessing who's going to Geneva, with the guessing being done by those who have an eye on the Swiss Alps. Because of the jamup on transportation and hotel facilities, there are a lot of people on edge. To give those who are going an idea of the layout in Geneva, we've reproduced on p. 75 a map of the city showing the meeting and exposition halls and the principal hotels. We'll be glad to send anyone who is going to Geneva a detailed map of the city. Just drop us a line.

Because of the great importance of the conference in general and foreign activity in atomic energy in particular, Editor Jerry Luntz will

NUCLEONICS

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About NUCLEONICS (Continued)

join the tourists crossing the Atlantic. In addition to information presented at the conference, he hopes to bring back with him a picture of the opportunities for U. S. companies abroad and the foreign competition for this business.

A final note on the conference story in this issue: We've listed all of the paper titles received by the UN by the time we went to press. We hope that we'll have for our July issue the names of the papers selected by the UN for oral presentation. We'll list these by giving the numbers of the papers as they appear on pg. 76 and following pages.

Reactors and isotopes. Because we felt the greatest interest in the Geneva conference would be in power reactors, we decided to devote a good part of one of our preconference issues to the subject—this month's. But this does not in any way mean that we're planning to reduce or dilute our coverage of other areas of the field. In fact, we're tentatively planning to devote an entire issue to applied uses of radiation sometime next spring. (We'd be delighted to receive ideas for this.)

Meanwhile, we'll publish next month an excellent article on use of radioisotopes to determine the velocity profile of moving liquids. Accuracy far exceeds that obtainable by other known methods; in fact, for the first time velocity can be measured extremely near the container wall.

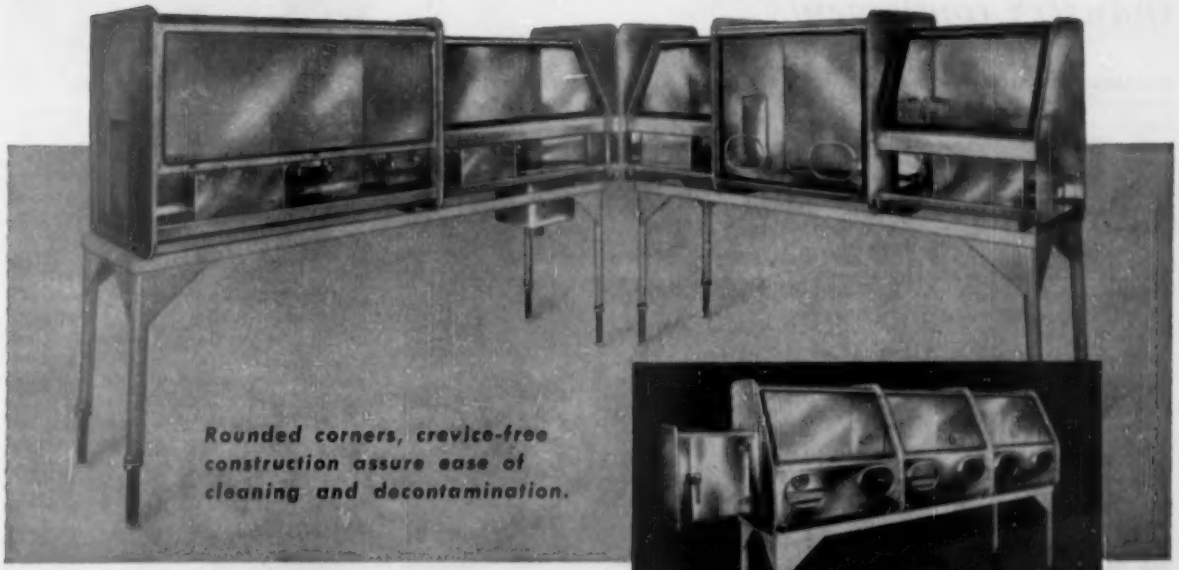
Next month we'll also publish the fourth Products and Materials survey. This one is on pumps for reactor coolants and includes pumps for both liquid metals and more conventional coolants. To assemble this information, we surveyed all known suppliers of possibly usable pumps, then collated and correlated the data they supplied about their products. Data is tabulated for both electromagnetic and mechanical pumps where models are standard enough that design features can be quoted. To back up this tabulation, we've included listings of manufacturers who primarily build to the user's specifications.

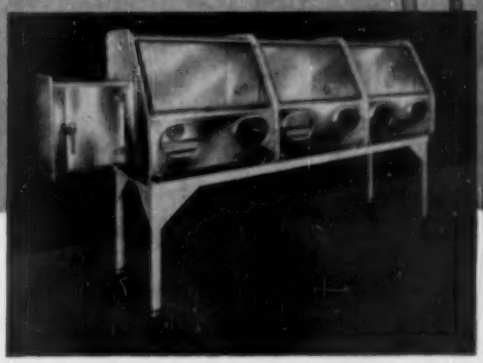
On the cover. To an editor, the front cover is like a billboard where he can display a new idea, important information. But one problem constantly arises—illustrating the idea and presenting the information in graphic form.

One shortcoming of the nuclear field is a paucity of photographs that are both high in illustrative quality and technically meaningful. We have a continuing need for photographs that meet these criteria. Suggestions for photographs, from individuals or organizations, will be welcome indeed.

—The Editors

STAINLESS STEEL
INTERCHANGEABLE DRY BOX SYSTEM
FOR HANDLING RADIOACTIVE MATERIALS





Some of the many assemblies possible with the interchangeable dry box system.

Here is a system of interchangeable dry boxes that offers several advantages:

- Offers selection of six basic enclosures and variations, 2 types of air locks.
- Completely flexible. Endless arrangements are possible to meet any condition.
- Standardized adapter plates and gaskets provide for connecting any type box to another, with or without air locks interposed. Units can be rearranged at any time.
- Standardized supports with adjustable legs accommodate any enclosure arrangement. Supports easily adapted to changes.
- All units promptly available for replacement, addition or re-arrangement.
- Variations in dimensions of any unit may be ordered to meet specific conditions.

SEND FOR TECHNICAL BULLETIN A-4 providing additional information about this interchangeable dry box system.

OTHER TECHNICAL BULLETINS AVAILABLE

• This is only a partial list. Ask us about the specific equipment in which you are interested.

A-1 Stainless Steel Low Intensity Dry Box
A-2 Stainless Steel Vacuum Dry Box
A-5 Biological Safety Cabinets & Research Enclosures
B-2 Dry Radioactive Waste Container
D-3 Typical Radio-Chemical Laboratory
E-4 Los Alamos Type Vacuum Rack Enclosures
E-5 Los Alamos Type Stainless Steel Fume Hood
E-6 Hanford Downdraft Fume Hood

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LIQUID WASTE CONTAINERS
LABORATORY STOOLS
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ENCLOSURES
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TRAYS

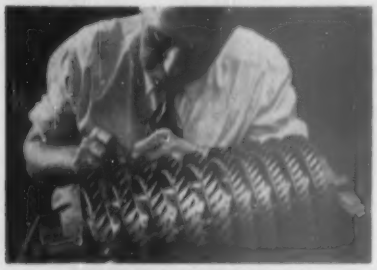
Solar's skills with special metals are "tailor made" for nuclear industry components

BUILDING FOR THE ATOMIC AGE calls for many special skills. For 28 years, Solar has been solving the problems that today confront nuclear engineers—extreme pressures, intense temperatures, corrosive conditions. Solar overcomes these hazards with highly precise fabrications of stainless steels, super alloys, titanium and other metals. This knowledge—expressed both in top quality contract production, and in the varied Solar proprietary lines—is now available to business firms and government agencies in the nuclear field.

Surface perfection required for AEC use

SOLAR BELLOWS for an AEC installation are shown above. They are one of several components built by Solar for nuclear processes. Other typical Solar products, shown below, are intricate turbine blades formed to withstand an inferno of heat, and stainless steel aircraft components that call for expert forming of half and full hard metal, and for miles of flawless welding.

Compressor rotor for Solar gas turbine



Solar builds first stainless nacelles

Current production at Solar also includes pneumatic ducting, aircraft engine components, and varied hard-to-build items for the petroleum, petrochemical, power, and other industries—both in the U. S. and abroad. A rapidly growing Solar product line is the building of complete control systems for engines and other devices.

Jupiter gas turbine is light, compact

GAS TURBINE ENGINES designed and built by Solar include the 50 hp Mars and the 500 hp Jupiter. Their simplicity, ease of maintenance, high power output in relation to size and weight, and versatility make gas turbines the ideal prime mover for many specialized applications.

Research facilities include 19 test cells

SOLAR OFFERS MORE than metalworking skills—important as they are in components for atomic installations. Complete production facilities are supplemented by a comprehensive research organization, and by design, development and production engineering groups. Solar research and engineering "firsts" include the first practical jet engine afterburner, the first practical hand-started gas turbine engine, and a host of others ranging back to the first stainless steel aircraft manifold in the "hedge hopping" era of aviation.

Task force studies complex titanium assembly

TOUGH SPECIFICATIONS are no surprise to Solar. Whether the job calls for prototype, limited or mass production, Solar has the men and machines to turn it out—to top quality standards, on time, and at reasonable cost.

PRODUCTION FACILITIES cover every type of metalworking—forming, machining, welding, brazing, casting, coating. Equipment ranges from precision experimental and tool shop machines to specially designed high production units. Solar has designed and built many of its own welding and fabricating machines for specialized needs. Some have proved so useful that they have been ordered by firms in the United States and Europe.

Testing stainless steel bellows

COMPLETE QUALITY CONTROL—to meet rigid aircraft and commercial standards—plus government source inspection, assures products that meet specifications. Solar plants in San Diego and Des Moines have 1,400,000 sq ft of floor space and thousands of skilled employees.

LET SOLAR PROVE how its skills are "tailor made" for the production of nuclear industry components. Describe your requirements, and let a Solar task force demonstrate that Solar is your logical supplier.

SOLAR
AIRCRAFT COMPANY
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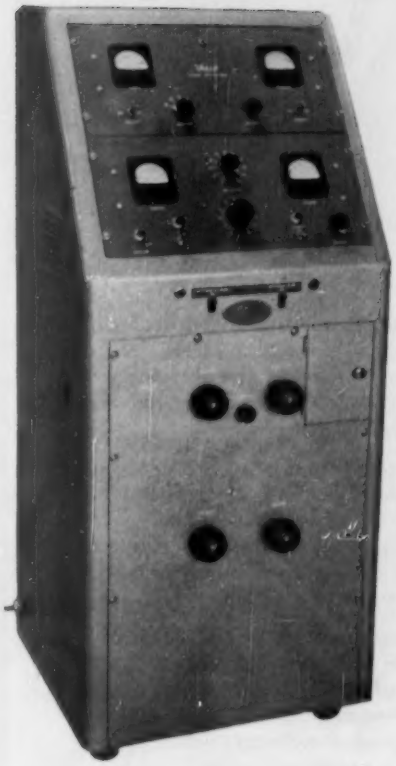
INFORMATION

For more information regarding any Solar product or service, write Solar Aircraft Company, Dept. B-11 San Diego 12, California

what's behind the MS-8 ?



Nearly a decade of producing leak detectors has resulted in this outstanding instrument of the mass spectrometer type. The MS-8 boasts a number of basic improvements. Chief among these is the Self-Cleaning Ion Source.* Electrical heating of this structure completely eliminates sensitivity decrease, commonly found in other instruments.

Another factor which places the MS-8 in a commanding position among leak detection devices, is its high useful sensitivity . . . it is practically non-microphonic.

Producing leak detectors of advanced design is nothing new at VEECO. Back in 1946, when some of the major particle accelerators were being built, VEECO's first Helium Leak Detectors were used in testing them.

The MS-8 is the culmination of VEECO's constant efforts in design improvement to meet the most rigorous demands of high vacuum engineering.

Veeco

VACUUM-ELECTRONIC ENGINEERING CO.

86 Denton Avenue, New Hyde Park, L. I., New York

B&W NUCLEAR STEAM

Selected for

CON EDISON'S ATOMIC POWER STATION

Progress toward large-scale use of atomic energy took a giant forward step with Consolidated Edison Company's decision to build a nuclear steam-electric generating plant at Indian Point, N.Y. The first privately financed atomic plant in history, Con Edison's 250,000 kw station will rank with the largest conventional fuel plants now being built.

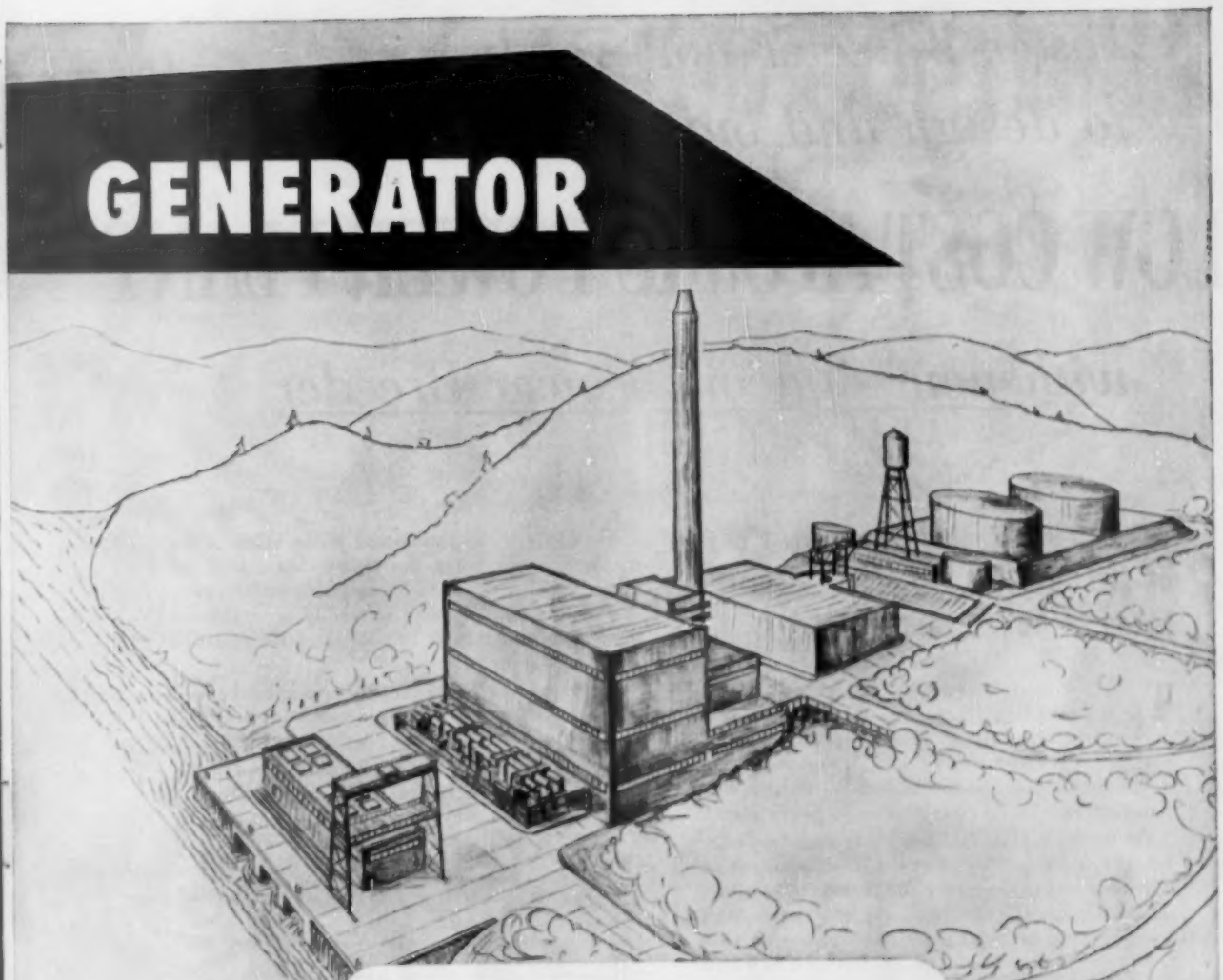
Con Edison's farsightedness in going ahead with private development of atomic energy is in the tradition established by its founders when electricity was first brought to New York City by Thomas A. Edison 73 years ago. To Con Edison, as to B&W, atomic fission represents a new and valuable source of heat — to be harnessed to develop electricity in a safe, efficient manner for the benefit of its customers.

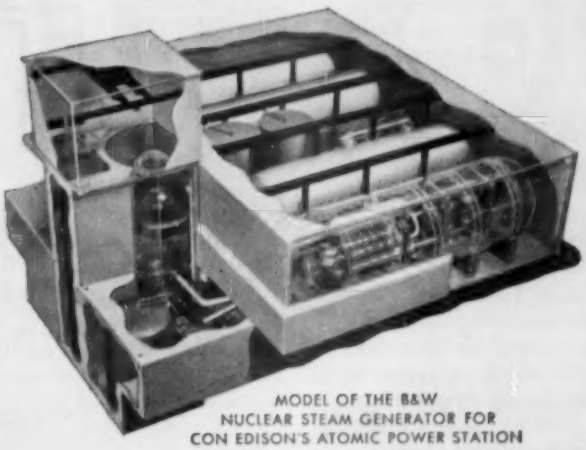
In selecting Babcock & Wilcox — an experienced supplier of steam generating equipment — to design, fabricate and erect the nuclear steam generator for the Indian Point plant, Con Edison recognized that a large share of the skills involved in nuclear power concern heat transfer, steam generation, fluid flow, high pressure piping, metallurgy, welding, and similar fields — in all of which B&W is a recognized leader.

Another basic consideration in this decision was that B&W, with its thousands of man-months of experience in nuclear power, is in a position to negotiate a fixed price contract for the required equipment, in the same manner as for a steam generator using conventional fuel. When its new fuel element fabrication plant now under construction near Lynchburg, Va., goes into operation, B&W will be capable of fabricating almost 90% of this equipment in its own shops.

Since the first days of the Manhattan Project B&W's experts have been called on for solutions to many of the special problems which arise in atomic energy. Today, more than 100 experienced B&W nuclear physicists and engineers, working in concert with B&W's large staff in conventional steam generation and its allied arts, are directing the wide range of atomic energy projects which B&W has been awarded. The best guarantee of realizing the full potentials of nuclear power at the earliest possible date is this combination of an intimate knowledge of atomic energy with nearly a century of steam generating experience. The Babcock & Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, N. Y.

GENERATOR





MODEL OF THE B&W
NUCLEAR STEAM GENERATOR FOR
CON EDISON'S ATOMIC POWER STATION

BABCOCK & WILCOX

ATOMIC ENERGY DIVISION

Foster Wheeler now ready to design and build

LOW-COST ATOMIC POWER PLANT

with new Aqueous Power Breeder

100,000-kw plant, at estimated cost of $21,000,000, will produce electric power at from 6 to 9 mils per Kw-hr!

The Aqueous Homogeneous Power Breeder type of nuclear reactor, heretofore regarded as a "long term" possibility, is *now being offered* by Foster Wheeler as a practical solution to the problem of high construction and kw-hr costs of atomic power plants.

On the basis of design data worked out by Foster Wheeler, a 100,000 kw plant can now be built at an estimated cost to the owner of $21,000,000 — within the price range of a conventional power station. And with the aqueous homogeneous power breeder, electric production costs could be as low as 6 to 9 mils per kw-hr — depending on system load characteristics, plant location and method of financing. Based on AEC estimates, 7-mil electricity would be competitive with 16% of the present market.

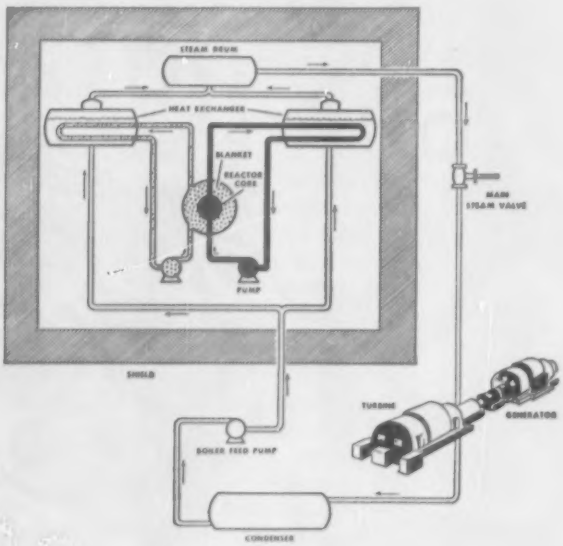
The aqueous homogeneous power breeder system has many inherent advantages. It uses a liquid fuel, and is self-controlling to the extent that, as demand on the steam generators increases, the reactor responds by releasing the heat required. Additional regulation is provided by controlling the concentration of uranium in the fuel solution.

An important feature is safety. The amount of fuel in the aqueous homogeneous core system is always consistent with the amount required for operation, because it can be added continually to the system to replace the fuel that is burned. To guard against hazards due to leakage, every piece of equipment containing radio-active material is enclosed in a separate, secondary vessel that will contain any leak.

Simplicity of operation and accessibility of the equipment are among the unique features of the plant. Although designed for minimum maintenance, every piece of equipment is readily accessible for maintenance or repairs without excessive radiation hazard.

Steam produced by the reactor system can be used to run a conventional turbo-generator.

For further information on the new type of nuclear power plant, write to *Foster Wheeler Corporation, 165 Broadway, New York 6, N.Y.*



Schematic diagram of an Aqueous Power Breeder System showing basic simplicity of this reactor type.

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Pressures of 8,000 psi result in only 4% to 5% permanent set. Line seals are retained longer when gaskets and O-ring seals are made of KEL-F Plastics.

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KEL-F Plastic is a thermoplastic and easy to fabricate. It is readily molded by extrusion, transfer and injection. Available in sheets, rods, tubing and film, it can be fabricated, heat formed, machined and heat-sealed by a growing list of experienced fabricators.

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KEL-F Plastic Dispersions have been developed for bake-coating of metallic surfaces that must be corrosion resistant, anti-adhesive and electrically non-conductive. These Dispersions can be applied by spraying, spreading or dipping.

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Advances in Applied Radiation

DEVELOPMENTS in the FIELD OF APPLIED RADIATION ENERGY, its APPLICATIONS and the APPARATUS USED TO PRODUCE IT

Van de Graaff Checks Jet Parts

HIGH VOLTAGE's new mobile 1-million-volt Van de Graaff x-ray generator has recently displayed outstanding performance in checking high precision castings for jet engines, which, because of their critical end use, must be accurately and fully radiographed.

Development of an improved method of radiographic inspection for a leading aircraft-engine manufacturer, based on this machine, will enable quality-control personnel to check over 6,000 castings daily, with greater reliability and substantially less time and effort than previously possible. Heretofore, radiographic inspection by the company was carried out with two units of different penetration characteristics, each used for a specific area of the casting. This arrangement was obviously undesirable from the standpoint of economy and production line efficiency. Using the new technique, all tests can be conducted with the 1-million-volt Van de Graaff accelerator.

This new x-ray generator promises to be a valuable asset to the engine company's quality control program. With the proper balance of low-energy and high-energy components in the x-ray beam, this unit can effectively radiograph sections of castings as thin as 1/16 inch, with adequate latitude to penetrate sections over one inch thick, all in the same exposure. Quality of radiographs is exceptional principally because of the Van de Graaff's tiny focal spot (less than 1 mm in diameter) which enables the use of shorter target-to-film setups. Furthermore, the complete installation cost, including the Van de Graaff, is under $30,000 – substantially less than for facilities heretofore available. (The April issue of FORTUNE magazine carried a full-page color photo of this million-volt radiographic machine on its mobile mount.)

Accelerator Sterilizes Drugs

Antibiotics, hormones, vitamins, anticoagulants, proteins and sulfa products have been successfully sterilized in experimental studies with radiation from a 2-million-volt Van de Graaff accelerator at the Upjohn Co., Kalamazoo, Mich.

Upjohn scientists report the company has achieved 100 per cent sterilization of these products with no harmful effects resulting in the drugs. The Upjohn Co. purchased its Van de Graaff accelerator in 1951 and was one of the first companies to initiate a broad study of radiation as a possible sterilizing agent. Its research in this field has continued since that time.

The pharmaceutical industry's interest in radiation stems from the important advantages promised by successful radiation sterilization of an already packaged product, or of a product just before it goes into pre-sterilized containers. Although progress toward this goal reportedly is encouraging – as witness the Upjohn announcement – widespread introduction of radiation-sterilized pharmaceuticals depends upon approval by the Food and Drug Administration of distribution for each product and upon development of an advantageous cost picture. The outlook for achieving both these prerequisites now appears favorable.

A Van de Graaff for Canada

The Canadian Defense Research Board, of the Department of National Defense, has purchased from HIGH VOLTAGE a 2-million-volt Van de Graaff particle accelerator to produce both positive ions and electrons for research use.

The machine will be installed at the Suffield Experimental Station at Alberta, Canada. The amount of the contract is $106,500.

The 2 MeV Van de Graaff produces beams of x-rays, electrons, positive ions and neutrons – each of known and controllable energy and intensity. This compact source of fundamental radiation is only 7 feet long and 3 feet in diameter.

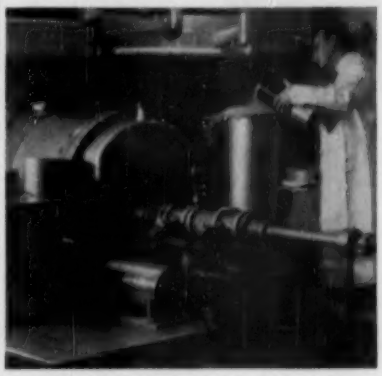
Shell Oil Neutron Research

Shell Development Company has recently put in operation a 2-million-volt Van de Graaff positive-ion accelerator for neutron production at its Exploration and Production Research Division in Houston.

This accelerator, first of its size and type to be purchased by the oil industry, is being used by Shell scientists to aid in the continuing search for possible oil-bearing structures deep underground. It will be employed primarily to duplicate nature's own radioactive processes under laboratory conditions.

It has long been known that certain materials found in nature constantly give off radiation but little has been known of the specific effects caused by such radiation over the centuries. Now, using the Van de Graaff as a powerful radiation source, Shell scientists can in a few hours produce the same effects in a rock sample that may have taken nature 10 million years or more to accomplish.

The accelerator also is being used in neutron activation analysis to identify specific elements in rock samples.



2-Million-Volt Van de Graaff particle accelerator installed at Shell Development Company, Houston, Texas.

Research Machine to Bell Labs

HIGH VOLTAGE recently announced the sale of a one-million-volt Van de Graaff electron accelerator to Bell Telephone Laboratories, New York, N. Y.

The machine will be used in a research program including electron bombardment of solids. It will be directed by Messrs. W. L. Brown and R. C. Fletcher.

ATOMANIA

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HIGH VOLTAGE ENGINEERING CORPORATION

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The Oak Ridge Swimming Pool Reactor in operation—forerunner of new research reactors for which L&N has engineered and built the first complete "package" control systems. This swimming pool reactor was designed at ORNL, operated for the Government by Union Carbide and Carbon Corp.

A new concept in nuclear reactor instrumentation...

L&N "Package" Control Systems

Nuclear reactors for private enterprise are no longer classified as "things to come." College research reactor No. 2—privately constructed, owned and operated—will be in service shortly at Pennsylvania State University. And No. 3, the University of Michigan Reactor, will follow closely.

Both the Penn State and Michigan Reactors will be completely controlled by L&N "package" reactor control systems, the first such package controls ever engineered—another "first" for Leeds & Northrup Company, pioneers in precision control; builders of the world's first electronic recorder.

The package concept involves far more than control instrumentation. It includes design services, engineering consultation, individualized fabrication of panels or cubicles, and more. It's an approach possible only by a group with L&N experience—dating from activation of the original Chicago Pile—using standard L&N instruments which can control reactors *routinely*, without the elaborate customizing so often required when velocity-feedback servo systems are used.

Package reactor control in its various aspects is described in our new brochure, "L&N Control Systems for Nuclear Reactors." We'll be glad to send you a copy. Just write to Leeds & Northrup Company, 4936 Stenton Ave., Philadelphia 44, Penna.

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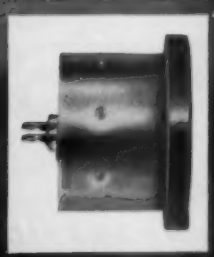

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for Gamma-Ray Spectroscopy

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- Relatively large flat cathode area (with minimum diameter of 1-11/16") permits excellent optical coupling between the phosphor and the cathode with the result that a maximum number of photoelectrons are produced for each scintillation. (Important in nuclear radiation spectroscopy because it offers the advantage of minimum statistical spread in output pulse heights).
- Spectral sensitivity response of 3000 to 6500 angstroms with maximum occurring at approximately 4400 angstroms. This sensitivity to blue-rich light makes the RCA-6655 well suited for use with organic phosphors such as anthracene and inorganic materials such as thallium-activated sodium iodide.
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ROUNDUP of Key Developments in Atomic Energy

LATE NEWS and Commentary

Thermonuclear Power

In contrast with continued U. S. reticence to acknowledge even the existence of the U. S. project, Russia has said it is working on harnessing the hydrogen bomb fusion reaction. The United Press quotes a Moscow broadcast: "Soviet scientists are endeavoring to direct the enormous reserves of nuclear energy contained in the hydrogen atom so that life will triumph on earth."

This report of Russian activity in this area seemingly does away with one high-level U. S. argument for not breathing a word about the subject—that doing so would tip our hands to the Russians on the fact that we are working in what some consider a potentially vital area and cause the Russians to dig into this field.

Although present commissioners of AEC are said to be unanimous in favor of keeping mum on the subject, a committee of scientists made the reverse recommendation not very long ago.

•

Reactor Hazards

In a combined warning and plea for cooperative action, C. Rogers McCullough, chairman of AEC's reactor safeguards committee, told an Atomic Industrial Forum meeting last month that unless the total reactor hazard problem is approached "satisfactorily" the industry may be bogged down. He said that there is a need for the development of safety standards (although not a code at this time) and that AEC needs advice from industry and from professional societies. There is also the need, he said, for both industry and government to compile data on: critical and transient experiments, corrosion tests, life tests on fuel elements, and effects of reactivity changes on reactor performance.

•

Bilateral Agreements

On May 31, Brazil and Colombia became the second and third countries to complete bilateral agreements with the United States for exchange of atomic energy information and materials. Like the first such agreement that was made with Turkey on May 3 (see p. 19), these provide for lease from the U. S. of up to 6 kilograms of contained U-235 in uranium enriched up to a maximum of 20%.

Actual signing of the agreements has to wait until initialed copies have been before the Joint Committee on Atomic Energy for 30 days while Congress is in session. Thus, to be valid, further agreements this summer have to be completed by June 15; Congress is planning to adjourn July 15.

It is expected that 12 to 18 bilateral agreements to be completed in time. Agreements with Israel and the Philippines are almost ready for initialing, and negotiations are underway with the Netherlands, Italy and Switzerland. More complex agreements are being negotiated with Belgium, Canada and Great Britain.

•

FDA Pessimistic on Potatoes

An uproar greeted Food and Drug Administration representative A. J. Lehman's statement that FDA "does not look favorably" on radiation treatment of potatoes to prevent sprouting. Until Lehman was queried directly, the May 25th Brookhaven National Laboratory conference on potato irradiation had proceeded normally.

Lehman backed up his statement by referring to his article in the Jan. '54

NUCLEONICS—pointed out that testing of irradiated foods must be lengthy when large portions of the population may be involved. He estimated 15 years would be needed for testing, but backtracked by talking about the situation changing within a year.

Reaction of the audience, which included a large segment of those working on radiation processing, was that 5 years should be the outside time for approval. Quartermaster Corps has already started wholesomeness studies, including human feeding. Some present later said FDA has to clarify its position and either start its own testing program or say it will accept Quartermaster results.

•

Kaiser, GE to Design ETR

AEC has awarded the contract for architect-engineer work and design for the Engineering Test Reactor (NU, May '55, p. 14) to Kaiser Engineers on a cost-plus-fixed-fee basis. General Electric will do some of the design as subcontractor to Kaiser.

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WHO Will Study Atom Use, Protection

The World Health Organization, a United Nations specialized agency, is embarking on a two-phase program in atomic energy. It will limit itself to international aspects it says no one nation can handle alone.

Protection against radiation hazards—primarily contamination of air, sea and land by wastes from nuclear plants—will be studied. WHO contemplates providing expert advice and collecting and disseminating data on community protection, health hazards, and radiation measurement.

Second phase of the program would be devoted to medical use of radioisotopes. Here too, WHO would act as an information clearing house. It would also set up a long-term program for training aid, based on fellowship consultants, study tours, and advanced courses.

Two committees will study these programs in 1956. A WHO budget allotment of $42,000 is being provided.

While study of fallout from nuclear bomb tests isn't included specificially in the WHO program, it's likely that some UN study will be set up this fall. Sweden has already announced its intention of leading the Scandinavian countries in proposing to the General Assembly this fall a study of immediate and long-range biological effects.

•

Defines State Problems

New conditions make it imperative for state governments to look closely at atomic activity and possible regulation. So said W. A. W. Krebs of MIT at last month's Atomic Industrial Forum meeting.

First, says Krebs, the legal status of persons and organizations in the field is changing: licensees will no longer be "wrapped as luxuriously in the cloak of federal immunity." Licensees may have to get state certificates of convenience and necessity; state rate regulation will have to consider proper allocation of possible excess costs; federal preference under the Atomic Energy Act may be at odds with state policy; waste disposal will have to be considered in light of water supply, which is largely regulated by state and interstate bodies. Finally, local zoning and construction codes may have to be met.

Second, the "locus of initiative" has changed. Decisions formerly made by the federal government will be made by industry, which is subject to other influences. An example is the building of a power reactor; a loss operation is more favorable in a state that taxes utility income rather than utility property. A state development agency could influence an industrial decision by being well-informed, aggressive, and cooperative.

Soviet, West Push Plans for Nuclear Power, Isotopes

With the United Nations atomic energy conference just two months away, the major world powers are quickening the pace at which they are disseminating atomic energy information and aid. Last month Britain signed an agreement with France for exchange of nonsecret data on development of peaceful uses of atomic energy. Iraq decided to send an official delegation to the U. S. to discuss atomic energy cooperation. And on May 6, the U. S. Congressional Joint Committee on Atomic Energy received a copy of the U. S. agreement for cooperation with Turkey (NU, May '55, p. 10). Under the law, the agreement lies before JCAE for 30 days before becoming effective.

Two points in the 10-year agreement with Turkey disturb some JCAE members, who feel they are written too loosely. First, more than the 6 kg of uranium-235 specified by the agreement can be transferred to Turkey if the Atomic Energy Commission desires. Second, not all "terms and conditions" contingent to the uranium lease are in the document—mutual agreement later is permitted.

AEC has indicated that much the same form will be used in bilateral agreements following this first historic one with Turkey. Several such agreements are now being negotiated.

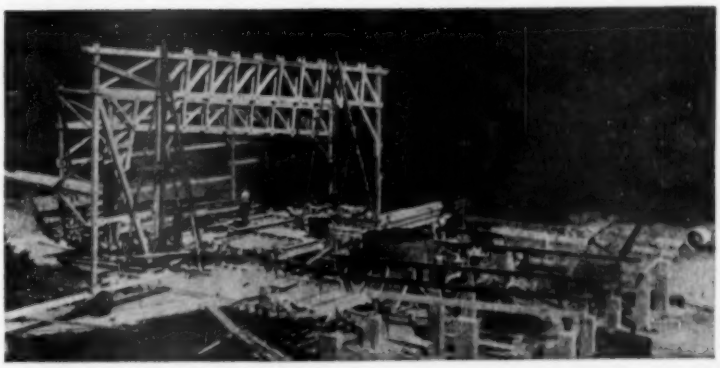
Soviet has plan too. While the West thus pursues the Eisenhower atoms-for-peace plan, the Soviet bloc is starting a plan of its own. The USSR recently signed agreements with its satellites that are said to provide Russian technical assistance, nuclear reactors, fissionable material and isotopes. Russia will also invite technicians and scientists to attend nuclear science courses.

The Soviet agreements were signed at the end of an 8-week visit to Moscow during March and April by representatives of the satellite countries. During that time, the delegates also visited nuclear institutes at Moscow, Leningrad, Kiev, and Charkov.

This Soviet program has aroused considerable speculation. The big question is just how much of it is political maneuvering aimed at providing fertile ground for propaganda. It's interesting that a worldwide technical assistance program transcending the Eisenhower plan was included as point 5 in the recent USSR disarmament proposals. These proposals come up before the UN General Assembly next fall.

Perhaps the clearest picture of what the Soviet bloc is doing will be given by the papers they present at the UN conference in August. The UN is striving to keep the conference nonpolitical; it has a good chance of succeeding (see article on p. 73). But the technical content of the Soviet bloc contribution will provide the real key—notwithstanding any political activity on the conference fringe.

Even before the conference, however, there are some indications that the Soviet plan is being pushed hard. But reports from Czechoslovakia, East Germany, Hungary, Rumania, and Poland also indicate that some snags are developing.



PURCHASE BY SWISS of pool-type reactor that will be part of U. S. exhibit at the UN Geneva conference, is being negotiated. As shown by picture, tank for reactor was in ground outside Palais des Nations last month. Framing of temporary building that will house unit had started. Meanwhile, at Oak Ridge National Laboratory, criticality tests with the Bulk Shielding Reactor proved that fuel elements and controls for Geneva reactor would work. Unit will cost U. S. $350,000; price Swiss will pay and where they will relocate reactor has not been decided

Czechoslovakia. Construction of a nuclear power plant is said to have started in the fall of 1954. But Czech newspapers have been pointing out that the first nuclear plants will be costly and could not be built without Soviet aid.

East Germany. It was announced some time ago that an atomic institute would be built in Buch, near Berlin. So far, however, not even the electric utility lines needed to serve the installation have been installed.

East German research so far has been of a theoretical nature. Increased activity is expected this year: two top-level scientists, Hertz

ELECTRON ANALOG is being used at Brookhaven National Laboratory to study operating characteristics and design of planned 25-Bev strong-focusing proton synchrotron. Electrons are injected into analog by 1-Mev Van de Graaff in rear, are then accelerated to energies up to 10 Mev in 45-ft diameter ring. Final 25-Bev proton machine will have an over-all diameter of about 850 ft. Over 80 people in BNL's accelerator development department are now working on the synchrotron project

ROUNDUP

and von Ardenne, have returned from a 10-year stay in Russia to head up the East German program.

Hungary. Perhaps the satellite leader in the nuclear field, Hungary reports that it is already using isotopes for control and measurement in many of its industries. A reactor capable of isotope production will be provided by Russia; Hungary will also use the reactor for experiments leading to nuclear power.

Hungary has also opened a new research institute near Csilleberg. Included in its equipment is at least one 1-Mev accelerator.

Poland. Like Hungary, Poland is planning to use a Soviet-provided reactor both for isotope production and power studies. It's reported that Poland is studying radiation effects and their possible industrial use.

Rumania. Claiming adequate uranium reserves to support a power economy, Rumania says it needs help in setting up processing plants as well as in building reactors.

Spreading of Power, Test Reactor Plans Continues

The multiple attack on the problems of nuclear power and other industrial use of reactors continues to widen both geographically and in scope. Within the past month:

- Aircraft reactor research activities by Pratt & Whitney Aircraft Co. of East Hartford, Conn., were split as some work was shifted to AEC's Livermore laboratory in California. Economy and time were factors.
- Arthur D. Little, Inc., continued studies of financing and site selection for an engineering research reactor. To cost about $15-million, the reactor would have more irradiation space and higher flux than the MTR. It would be owned by an industrial group, Little would operate it and rent space. Plans are expected to crystallize in two or three months.
- Minnesota Nuclear Operations Group was formed by General Mills, Inc., Minneapolis-Honeywell Regu-

Washington Report

The hottest issue in the civilian reactor development program went supercritical recently in a touchy exchange between Senator Clinton P. Anderson (D, N. M.), chairman of the Joint Committee on Atomic Energy, and Commonwealth Edison Co. officials.

At a dinner meeting April 27, during a National Industrial Conference Board management course, Anderson remarked that the four utilities groups that submitted proposals under the Atomic Energy Commission's power demonstration reactor program were making a move that would hurt them in the long run. He said their plans were so bold, and went so far in an attempt to get the atomic power industry off the ground, that the companies for their own sakes should have gone one step farther and side-stepped the demonstration reactor program and applied only for licenses to operate reactors, as did Consolidated Edison Co. of New York.

This comment irked Commonwealth. The company is a member of a seven-company group (Nuclear Power Group, Inc.) that submitted a proposal for a 180,000-kw boiling-water reactor under the demonstration program's April 1 deadline.

Although its group applied under a program which promised federal aid in building acceptable reactors, Commonwealth disliked intensely being compared unfavorably with Con Ed. In a letter to Anderson—written the day after his statement—Commonwealth made it clear it was seeking nothing more than Con Ed had requested.

This is quite true. Although Con Ed did not apply under the demonstration reactor program, the New York utility has the same chance to qualify for government aid as do those who came in under the program. Commonwealth Edison realized it too could do this, but felt it should submit its request for a license in conformity with an announced AEC development program.

Actually, the only damage done in the Anderson-Commonwealth exchange was ruffling of pride. The Chicago utility wants the federal aid for which it qualifies under the law, but it also wants the public to know that it isn't asking for more than others are.

But the matter did serve to point up something Anderson has repeatedly emphasized: the danger of subsidization of civilian reactor development, and the resultant continuation of government control over the industry.

Anderson particularly dislikes the power demonstration reactor program. He thinks its requirements for participating companies to sign agreements with AEC will prolong government supervision of the civilian reactor program. And he feels its provisions for government financial aid provide too much room for outright subsidization of privately-owned nuclear power plants. Anderson thinks the demonstration reactor program holds out too much promise, that it seems to promise more aid than is actually permitted by law.

AEC doesn't think so, and it's stuck to its plans. However—and Anderson's prodding is at least partially responsible for this—AEC now recognizes the dangers its program contains. It realizes the demonstration program needs strict policing to keep its financial aid provisions from snowballing into subsidies.

lator Co., and Northern States Power Co. to spot nuclear activities of benefit to the state's industries.

Plan for A-Ship Prompts Flurry of Other Proposals

President Eisenhower's plan for a nuclear-powered freighter (NU, May '55, p. 9) has precipitated a raft of other ideas for nuclear vessels. These range from thoughts on a superliner to Congressional intentions to plug for a second cargo vessel—and counterproposals to help other nations develop their nuclear knowhow.

Some details of the President's proposal seem to be firming up. Guesses are it will entail a 10,000–15,000-ton ship about 500 ft long, with an 18-knot speed. The $33.6-million vessel would be built with $12.65-million for the hull from Maritime Administration funds and the $21-million reactor from AEC funds. The reactor would be similar to the one used on the *Nautilus*. Ship would take about 24–30 months to complete and would cost $500,000/yr to operate. After hearings by the House Merchant Marine and Fisheries Committee, its chairman, Rep. H. C. Bonner, warned that the military seemed bent on frustrating the project with its intention to hold close rein on propulsion reactors. Rep. Bonner said he will propose a second nuclear ship whose reactor will take about five years to build.

AEC and the Navy plan to build in Idaho a test model Large Ship Reactor (LSR) for carriers and cruisers.

United States Lines is considering using a reactor to power the successor to the firm's liner *America*. The proposed ship probably will be comparable to their 53,000-ton liner *United States*, which is 990 ft long and carries 2,000 passengers.

The interest stimulated by the President's plan also prompted other shipping interests to busily unveil artist's conceptions of nuclear ships. But amidst the excitement, answers to two questions hold the key to Congressional action and the immediate future in this field: (a) Is the exhibition ship the best way to demonstrate our peaceful accomplishments and intentions? (b) What is the best way to foster development of economic reactors for merchant vessels?

About the Industry

Congress and the Administration are hacking away at one of the major obstacles to nuclear power development: the public utilities holding act. This 20-year-old piece of legislation makes any company holding 10% or more of the stock of a generating company a holding company. Holding companies are subject to regulation by the Securities and Exchange Commission, including approval of financing.

Already subject to Federal Power Commission and/or state public utility control, most power companies shy away from SEC control. But the cost of nuclear power plants, especially at the present state of the art, dictates multicompany backing.

One way companies working together on nuclear power plants avoid the holding act is to form nonprofit corporations whose activities are confined to power research. That's the route Atomic Power Development Associates and Nuclear Power Group are taking. The question is: What happens if their experimental plants are improved to the point where they can produce competitive power? Can they retain their exemption from the holding act if AEC declares that the type of reactor they have built is a commercial facility under the Atomic Energy Act of 1954?

APDA says it will sell out to one of its backers if AEC makes such a ruling.

First attempt in Washington to alleviate the situation is a bill introduced by Rep. Thomas A. Dodd (D., Conn.). This bill would negate the 10% rule for a company not otherwise a holding company if it met three tests: that it and the other owning companies have interconnected facilities and are within economic transmission distance of the jointly owned plant; that the entire output will be sold to the government or to the owning companies; and that issuance of securities by the jointly owned company is subject to the jurisdiction of a state or Federal agency.

Actually, some of the nuclear power teams don't have interconnected facilities. But Rep. Dodd's bill hasn't yet been commented on by the Administration; it's by no means the final word on easing of government restrictions.

Not only technical firms are taking advantage of AEC's new access program to get a look at classified information (NU, May '55, p. 13). The country's biggest brokerage house—Merrill Lynch, Pierce, Fenner & Beane—has signed an access agreement with AEC. The firm will study data in the confidential or "gray" area; L-clearances will be granted to selected personnel.

W. H. Smith, managing partner of the Wall Street firm, says, "We are sure that when our firm has access to information on atomic energy we can help provide the needed capital for the development of atomic energy for peacetime uses."

Access agreements aren't the only way to get investment information in the atomic energy field. Another way is to hire a consultant or a consulting firm to evaluate the field. Mutual Life Insurance Co. of New York and First National City Bank, also a New York establishment, retained Arthur D. Little, Inc., recently for advice on investment and banking opportunity in the atomic industry.

ROUNDUP

RAW MATERIALS

AUSTRALIA: ships first commercial ore to U. S. With the first shipment worth almost $1½-million, revenue from shipments of the first 18 months will be used to repay the £3-million used to set up the treatment plant.

MADAGASCAR: makes first ore delivery. Société les Minerais de la Grande Ile, the company exploiting a new uranium-thorium deposit, made its first delivery to the French AEC Dec. 14. This shipment, valued at $10,000, provided 3 tons towards the 15 contracted.

Proven reserves of the initial deposit being worked are 70 tons; however potential deposits cover 600 mi². Aerial surveys are being conducted in an attempt to find the principal vein.

FRANCE: plans exploiting large uranium deposit near Limoges. Found 5 years ago and believed to be the largest deposit in France, the 250-meter-thick seam at La Crouzille will be commercially exploited by a company formed by the Limoges Chamber of Commerce.

ARGENTINA: fixes 5-yr uranium price schedule. With the National Atomic Energy Board as sole buyer, the government has set prices for ore containing a minimum of 0.20% U_3O_8 as: 280 pesos/kilo U_3O_8 per ton of ore plus 100 pesos/kilo U_3O_8 ex-

Reactor News

Two more utilities join plan for Nuclear Power Group reactor. Central Illinois Light Co. and Illinois Power Co. have joined Nuclear Power Group's original 5 firms in sponsoring a $45-million boiling-water power reactor to be built on a 750-acre site near Morton, Illinois, which is 47 miles southwest of Chicago (NU, May '55, p. 11). Commonwealth Edison, which will own and operate the plant, will provide the site, cover overhead costs, pay $4.5-million for transmission facilities, and put up $30-million towards the plant; other firms will invest $15-million for the experience to be derived. For its investment, Commonwealth Edison is expected to be able to generate electricity that will be approximately competitive with the 7–8-mill/kwh power from new coal-fired plants in its area. If AEC approves the plan, General Electric will build the 180-Mw plant as prime contractor with Bechtel Corp. as engineer-constructor. For more information on this plan, see "Washington Report" on p. 20.

British firms team up to build nuclear power plants. Seven Tyneside companies have accepted an invitation by the electrical-engineering firm of Messrs. C. A. Parsons and Co. Ltd. to form a separate $2.8-million-capital corporation to design and build complete nuclear power plants in any part of the world.

Funds asked for U. of Florida reactor. Florida's Governor LeRoy Collins has requested appropriation by the state legislature of $500,000 towards construction of a $3-million reactor facility for the University of Florida's engineering and industrial experiment station. Balance of needed funds would be provided by private sources. Reportedly, the APPR-type reactor would supply the University 20,000 lb/hr steam at 500° F as well as being used for experiments.

Subcritical reactor for NYU. A 1/300th watt subcritical reactor consisting of a 5-ft tank of water with a Po-Be neutron source and 2 tons of uranium rods is scheduled for September installation at New York University's campus in the Bronx. To be tested at Brookhaven National Laboratory, the unit will develop a neutron flux of 10^4/cm²/sec and will be used in the school's new master of nuclear engineering curriculum.

Fuel future crystal-balled at Forum session. Last month's meeting of the Atomic Industrial Forum included estimates of trends in reactor fuels over the next decade (for more on over-all trends, see p. 80).

A. Stewart of National Lead Co. sees that in the future 40% of feed to fuel processing plants will be scrap, a percentage similar to that in other industries; 99.8+% concentrate may be produced in the mills by use of solvent extraction techniques. He feels that more than 10 new mills (costing more than $15-million) may be needed to fill needs of the nuclear power industry.

In evaluating fuel element fabrication business, Carroll L. Wilson of Metals & Controls Corp. estimates that for several years only two cores will be fabricated annually for the highly enriched propulsion reactors—and most of this work will be done by AEC. For research and small package power reactors (including the MTR), more than 40 cores will be furnished by industry in the next three years. He estimates industry will handle about 100–150 metric tons of partially enriched uranium for initially loading two or three large power reactors by mid '58.

N. A. Spector of Vitro Corp. estimates that for a given electrical capacity, reprocessing throughputs for aluminum alloyed fuel elements are ⅓rd those for natural uranium unalloyed elements, and zirconium alloyed elements have throughputs ½rd those of the Al elements. Cost of waste disposal for products from reprocessing Al elements runs twice as high as for the unalloyed, with Zr element reprocessing running 3 or 4 times higher than the unalloyed. Reduction of reprocessing costs as reactor capacities increase indicates desirability of using central reprocessing facilities. For instance, he estimates it might cost under $20/gm of natural uranium to treat fuels from 3,000-Mw-capacity plants, but it would cost up to $140/gm for a 40-Mw unit.

Expenditures on disposal of wastes from power reactors were estimated by R. A. Brightsen of Nuclear Science and Engineering Corp. With a U^{235} burnup of 7% for a 70,000-Mw industry in 1964, about 60,000 tons of uranium will be reprocessed annually. If 1,000 gal of liquid waste result from treating each ton and if it continues to cost about $1/gal for evaporation, semi-permanent fixation in concrete or clay, and land burial, then disposal will cost $60-million, or 0.4 mill/kwh for 25% efficient reactors. Brighter picture would result from tenfold cost cut projected for future processes.

ceeding the first 4 kilos per ton. For less than 0.20%, price will be according to the individual case.

When purchases from a given mining group reach 500,000 pesos, further purchases will be suspended until the Board verifies the mine's resources. Mine proprietors must furnish any information required of them by the Board. According to the new Constitution, minerals and natural energy resources are the property of the State.

UNITED STATES: contracts for uranium-ore processing mill. A contract for constructing and operating the first mill outside the Colorado Plateau was signed by the AEC and Mines Development, Inc., April 28. Located at Edgemont, S. D., the mill will process ores of the Black Hills region; ore is currently stockpiled at Edgemont. This brings to 10 the number of mills processing domestic ore.

New lithium-chemical manufacturer formed. American Potash & Chemical Corp. and Bikita Minerals (Private) Ltd. have formed American Lithium Chemicals, Inc., to manufacture chemicals from the Southern Rhodesian lepidolite deposits, described as the largest known lithium deposits in the world. The new company's $6,600,000 plant is located near San Antonio, Texas.

Reactor suggested for oil-shale reduction. By piping reactor-heated gas or liquid metal into oil shale, Clarence I. Justheim, Salt Lake City oil man, believes the shale can be melted and pumped to the surface. He has applied for a patent.

Uranium production hits stride. Since the AEC domestic uranium program got under way in 1948, U. S. private uranium activities have expanded to about $100,000,000 per year, says Jesse Johnson, director of AEC's division of raw materials. In the past two years, three Canadian uranium projects have been privately financed with $70,000,000, in addition to other government and private projects. South African mill investment will be about $180,000,000 upon completion of the present program. Australia and Portugal present major expansion possibilities. A Canadian estimation is that by 1957 Canada will be producing nearly $200,000,000 worth of uranium a year, the U. S., $80,000,000, South Africa, $100,000,000, and the Belgian Congo and Australia, $60,000,000 each.

Industrial Applications

Radioisotopes trace liquid carry-over in solid-liquid separation. To determine the amount of liquid left in solids following phase-separation operations, a radiotracer can be added to the liquid. This technique also can be used to find the packing fraction of solid particles. Packing fraction is difficult to calculate unless the particles are uniformly sized and shaped. R. A. Sullivan of National Dairy Research Laboratories uses iodine-131 labeled human serum albumin to trace entrainment when milk is separated in an ultracentrifuge. Requirement for the tracer is that it not react with or penetrate the solid.

Neutron activation measures silver-plate thickness to 5% in 5 minutes. Using the 2,500 neutrons/cm²/sec from a 200-mg Ra-Be source to form radioisotopes of silver, and a special G-M tube to count the activity formed, silver coatings are measured to 0.00005 in. Ag is 0.1–1-mil thick, forming a conductive coating inside 50-mil thick brass wave-guide tubes. Method works despite formation of Cu and Zn radioisotopes because Ag has a larger cross section, decays faster, and is not subject to self-absorption. Actual ratio of silver/brass count is 7.5, and brass count is subtracted as constant background. Irradiation and counting periods are 2.5 min each. Only 15 sec is allowed between the two, as the Ag isotopes have 24 and 140 sec half-lives. This nondestructive test was devised by H. V. Watts, C. A. Stone and L. Reiffel of Armour Research Foundation.

Quick test for mold erosion allows lower molding costs. Abrasive effects of plastics on metal molds are being determined in a 30-minute test by the General Electric Co. phenolic engineering laboratory. Worn molds cause costly shutdowns in producing molded plastics. The previous testing method took 3 weeks per test, was not positively reproducible, and testing costs were much higher. The present method determines 0.5×10^{-5}% metal in plastic. Procedure is to use a standard transfer-molding machine with the sprue bushing (through which plastic flows) made radioactive by neutron bombardment. As plastic flows through bushing it erodes metal; counting radioactivity of molded part determines how much erosion has taken place. Testing is done by running a comparative test against a standard compound each time, thus automatically correcting for decay of activity of bushing and metal inside plastic. Activation of the steel bushing is done at the Brookhaven reactor.

Pre-smoke fire detector depends on radium ion source. An improved fire detector now on the market operates on the low mobility of combustion-gas ions compared to air ions. The molecules are ionized by alpha particles from a small amount (probably less than 1 mg) of radium. When the air ions enter the detector's collection chamber they produce about 3×10^{-9} amp. But heavy combustion particles move slower and are almost all neutralized before reaching the electrodes. This means that current drops sharply if a fire starts. A second ionization chamber inaccessible to room air serves as a standard current source. Pyrene-C-O-Two, who market the detector, claims that its cost would be lower than a comparable smoke-detection system in a large installation.

ROUNDUP

News in Brief

Cosmotron resumes operation. After a 5-month repair and overhaul job, the Brookhaven National Laboratory machine is at its full 3-Bev energy and accelerating about three times the number of particles it did before shutdown (NU, Dec. '54, p. 6). The schedule is from 16 to 24 hr/day, 5 days/week.

Norwegian isotope production doubled in '54. Isotopes produced at the Institute for Atomic Research, Kjeller —a total production figure is not reported—were used in Norway, the Netherlands, Denmark, and Sweden.

Japanese survey team recommends acceptance of U. S. aid. Report submitted to Japanese government by group that tourned around globe to see atomic facilities, recommends that aid be accepted only if it does not involve undue secrecy or hinder independent research. Tokyo expects U. S. offer to involve as much as 220 lb of uranium.

AEC invites governor's representatives to discuss licensee health and safety regulation. At a meeting this month with state officials, AEC will solicit suggestions on regulations in preparation to protect the operators and the public in licensees' use of source, special nuclear, and byproduct materials. These regulations are in addition to those published April 12 on licensing and security (NU, May '55, p. 12).

US Chamber of Commerce recommends less security restriction of nuclear data. The policy adopted at the 43rd annual meeting calls for AEC to measure declassification against a yardstick of industrial progress; to provide licenses and materials on a long-term, broader basis; and to end compulsory licensing of patents. The Chamber also says that the federal government should not compete with private atomic power.

Zirconium price reduced up to 40% by Carborundum Metals Co. Reductions per pound are: from $22 to $14.40 for 500 lb and over of commercial-grade ingots; from $22 to $14 for low-hafnium sponge; and from $33 to $23.04 for low-hafnium ingot.

AEC awards 68 life science and physical research contracts. Included are 10 life science and 5 physical new-project awards, plus 25 life science and 28 physical research contract renewals.

Army studies nutritional value of fission-product-irradiated foods. Nine volunteers finally started on a diet of 13 irradiated foods at the Medical Nutrition Laboratory, Fitzsimons Army Hospital, near Denver, May 9. The foods are processed by AEC at Idaho Falls and flown to Denver.

Navy revises atomic submarine program. Next year's construction program is being stepped up from 3 to 4 nuclear-powered submarines, with conventional submarine construction cut from 5 to 4. Eight atomic submarines are now planned, including the *Nautilus*. The *Sea Wolf* will be launched in July.

Chile plans Center of Nuclear Studies. The center is being created under the auspices of several universities, the Chemical Engineers Institute, and the Chilean Chemical Society.

Bell Telephone Laboratories plans accelerator studies. Using a 1-Mev Van de Graaff machine purchased from High Voltage Engineering Corp., W. L. Brown and R. C. Fletcher will direct a program including electron bombardment of solids.

Ninety-eight colleges surveyed have 234 on staffs with nuclear engineering experience. These break down by department, reports C. E. Dryden, Ohio State University, as: civil, 26; chemical, 80; electrical, 50; mechanical, 43; metallurgical, 35.

Nuclear power liabilities exceed private insurance market capacity. Although the casualty insurance industry is prepared to insure private users of nonfissionable radioactive materials, Joseph H. Forest, vice president of Liberty Mutual Insurance Co., said that it cannot at present handle the power industry liabilities—the latter are in the range $100,000,000–250,000,000. Smaller operators, e.g., of research reactors, will have to "reach a compromise between what they would like to have and what they can afford." A joint insurance industry-AEC committee report is due this month.

Union Carbide building Cleveland lab. The company's new National Carbon Division will develop materials for the nuclear and electronic fields.

Austrian industry finds extensive radioisotope applications. Austrian radioisotope use has expanded from 23,000 mc in 1952 to 54,000 mc in 1954, with industry the biggest user by far. Almost every steel mill, nitrogen and construction works, and paper, textile, plastic, and rubber industries are becoming large users.

Utilities to discuss nuclear energy. The National Association of Railroad and Utilities Commissioners will conduct a panel discussion covering nuclear power, regulatory problems, and health, safety, and legal aspects at its annual convention at Asheville, N. C., Oct. 24–27. The 6-man panel will include utilities and one AEC member.

Nuclear chemistry conference to be held June 27–July 1. This year's Gordon Research Conference, to be conducted at Meriden, N. H., will cover theoretical aspects; low-energy, high-energy, and heavy-ion nuclear reactions; nuclear fission; neutrino experiments; positronium; and radiochemical separations. Those interested in attending, contact the chairman Anthony Turkevich, Institute for Nuclear Studies, University of Chicago, Chicago 37, Ill.

Texas will create state advisory committee on atomic energy. Gov. Shivers wants advice on effect on transportation, city planning, power, and communications.

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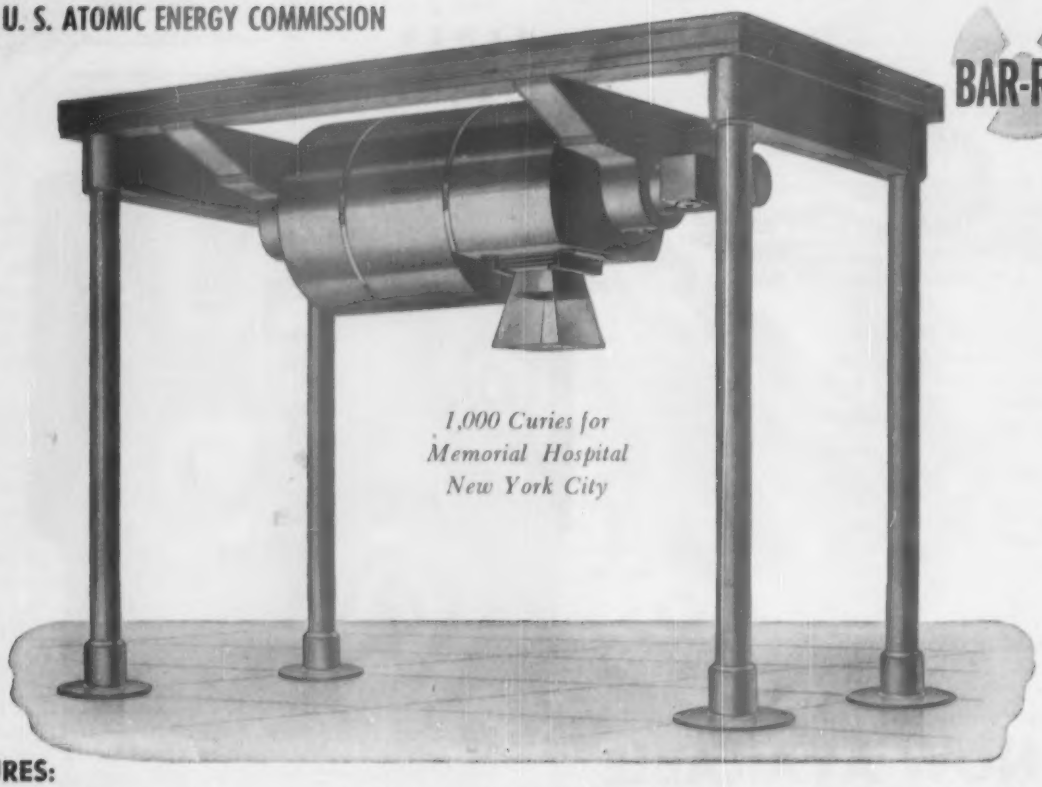

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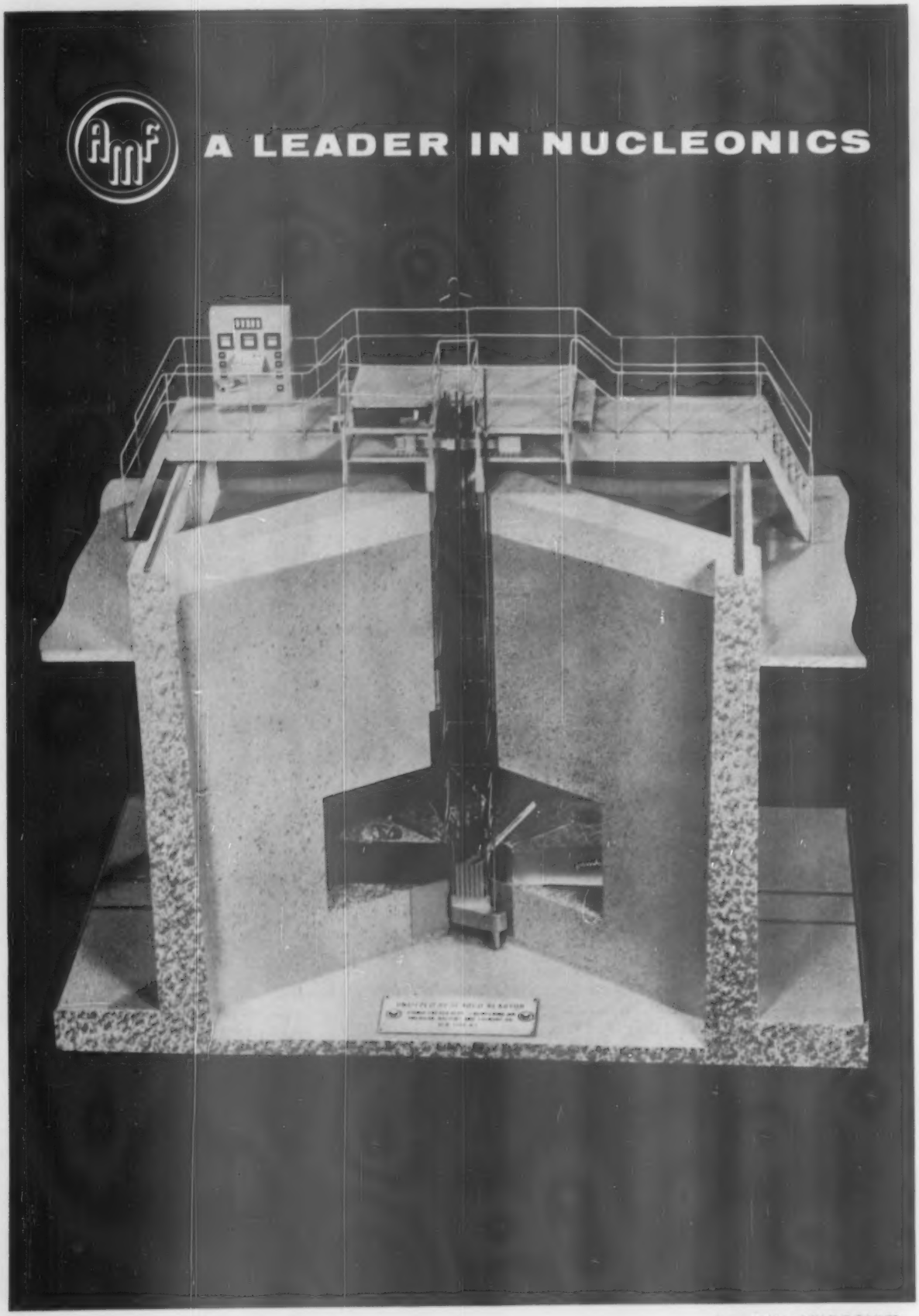
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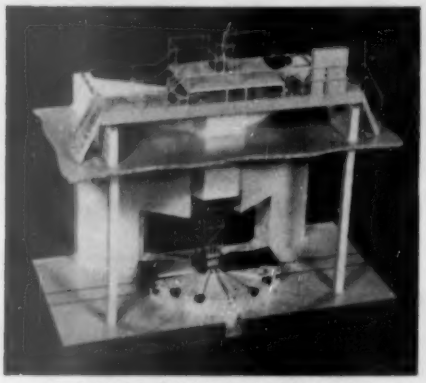

Scale Model of AMF's Unitized Research Reactor (pool and rear shielding cut away). Pool-side view at left.

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Basic AMF activities in the field of atomic energy include:

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The design and development of **complete research reactor systems**, including "heavy water", "swimming pool", "pressurized water", "boiling water", and "gas cooled" types.

An engineering conceptual design for **power reactor plants** for industrial power supply, and active consultation with several **public utility groups** investigating nuclear power plants.

Research and development in the field of "applied nucleonics", including the **radiation sterilization of foods.**

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Specific AMF projects completed or under contract include:

Design and construction of special control rods and remote processing equipment for the **Hanford Engineering Works** of the **AEC.**

Design, development, and construction of the complicated control, handling, and processing equipment for the **Savannah River Facility.**

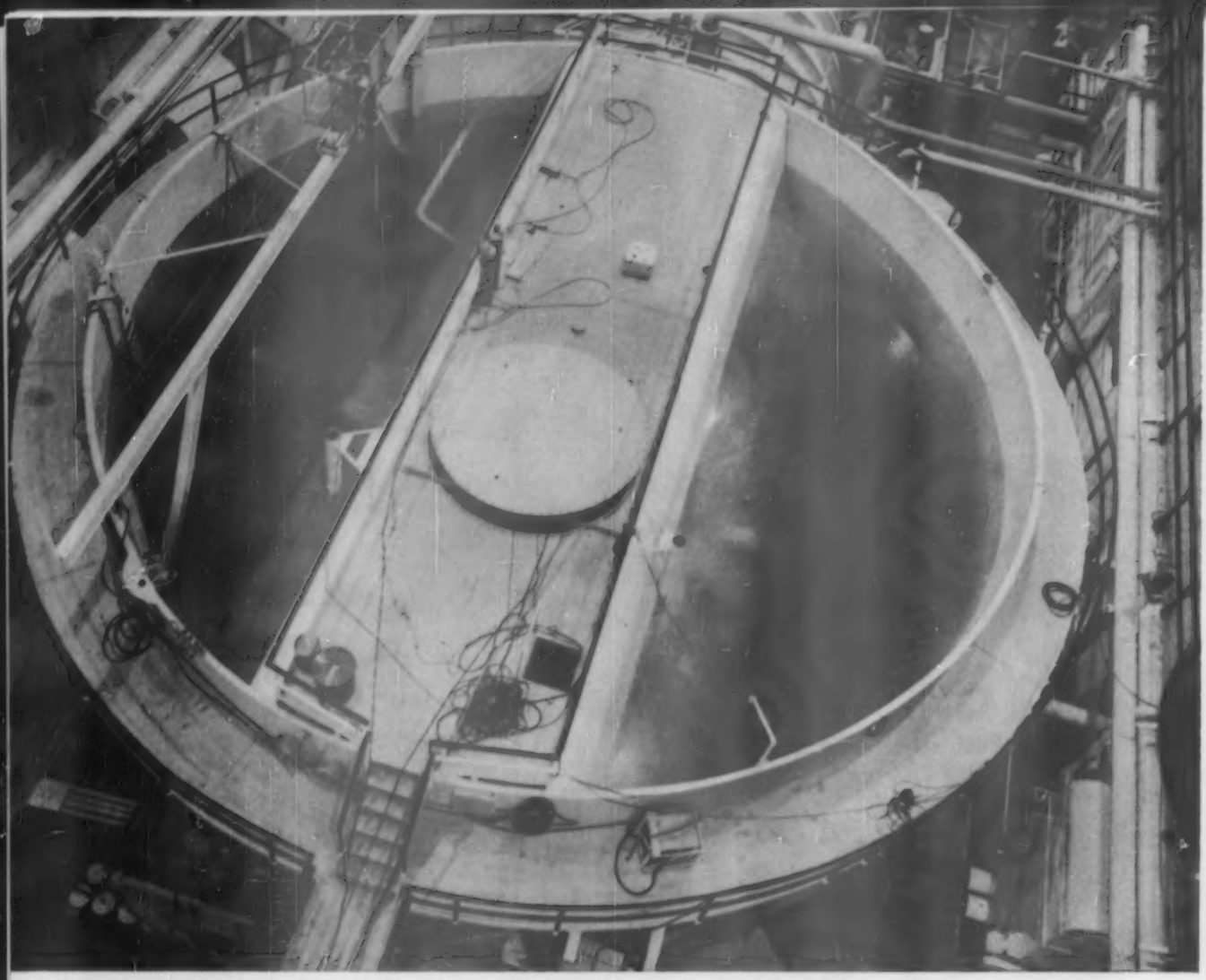
Construction of an AMF-designed "unitized" reactor of the "swimming pool" type for **Battelle Memorial Institute,** Columbus, Ohio.

Development of reactor control and handling equipment for the **Atomic Power Development Associates,** Detroit, Michigan.

Supply of complete AMF-designed "unitized" control units for **Oak Ridge National Laboratory.**

Design of a "pool" type, "unitized" **New York Area Industrial Reactor** to be sponsored jointly with representative firms in other leading industries.

Core and shielding in this AMF Research Reactor are similar to designs developed in AEC laboratories.



Atomic reactor built by Westinghouse for AEC is in this land-locked submarine hull at the National Reactor Testing Station in Idaho. It went into operation May 31, 1953.

2 FULL-SCALE ATOMIC POWE

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The *first* full-scale nuclear power plant designed, developed and built specifically to produce large amounts of usable power, was built by Westinghouse for the Atomic Energy Commission and the U. S. Navy. It has been operating successfully, at the National Reactor Testing Station in Idaho, for almost two years.

The *second* full-scale nuclear power plant designed, developed and built specifically to produce large amounts of usable power, was built by Westinghouse for AEC and U. S. Navy. It powers the revolutionary submarine, *Nautilus*, which has joined the fleet after dramatically successful undersea trials.

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The Nautilus, first atomic sub. It is propelled by an atomic power plant built by Westinghouse for AEC and the U. S. Navy. It went to sea January 17, 1955.

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FIRST atomic engine to drive submarine went to sea January 17, 1955. Westinghouse now working on atomic engines for two additional submarines.

FIRST atomic reactor for full-scale peacetime electrical generating power plant in the U. S. is now being built by Westinghouse for AEC; reactor to be operated by Duquesne Light Co., Pittsburgh, Pa., which also will build and operate the electric generating portion of the station.

FIRST contract to develop atomic engine for large surface ship . . . awarded to Westinghouse, October 15, 1954.

FIRST privately-financed factory devoted exclusively to building parts for atomic power plants, at Cheswick, Pa. Started operation December, 1953.

FIRST substantial quantities of controlled atomic power produced at the National Reactor Testing Station, Idaho, May 31, 1953. Reactor built by Westinghouse for AEC.

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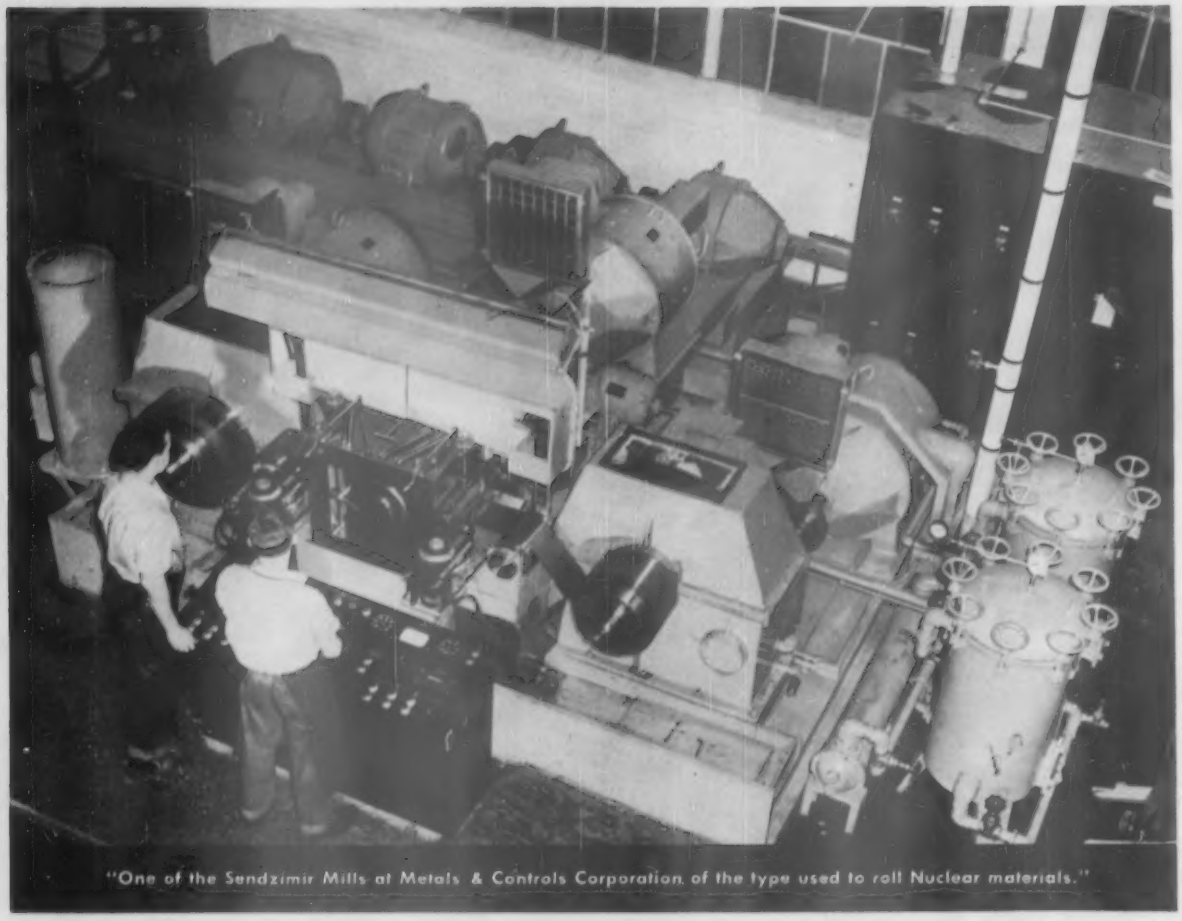

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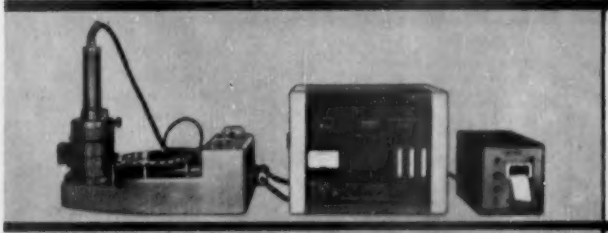

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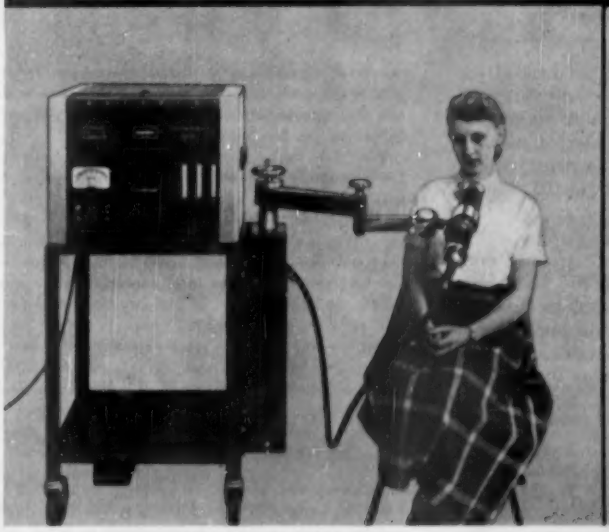
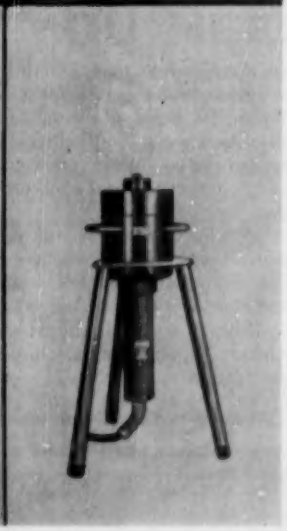
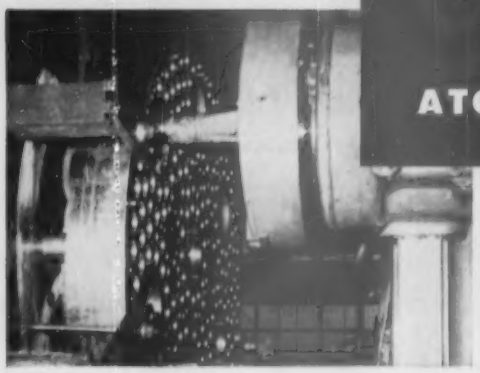




One of Combustion's two plants at Chattanooga, Tenn., showing artist's renditions of new facilities now being built: (A) Nuclear Building; and (B) Wharf for water shipment of large nuclear power components.

LOOKING TO *our* ATOMIC FUTURE



Part of the nuclear power plant for the submarine, Sea Wolf, in process of manufacture in C-E shops. Precision workmanship is critical.

Cleanliness approaching good hospital practice is essential in the manufacture of nuclear reactor components.

Because Combustion took a long hard look at its atomic future years ago, today it is well along in its program for keeping abreast of nuclear power progress. And we intend to stay abreast of this progress for the very good reason that *power is our business*, whether its heat source is fossil, atomic or even solar energy.

How soon nuclear fuel will become economically competitive with fossil fuels has been only one factor in our planning which, from the start, has reflected the view that atomic power was here to stay . . . that it would be of growing importance in our future . . . and that our chief concern should be "how" rather than "when".

Where does Combustion stand today?

In the past year, we've nearly doubled the technical staff of our Nuclear Power Division, and we expect to maintain this rate of growth for some time to come.

Presently, we are building the huge reactor vessel for the country's first commercial-size nuclear power station — the AEC-Duquesne Light plant at Shippingport, Pa. Last year we completed manufacture of nuclear components for the prototype of the submarine, Sea Wolf, and we are now well along with the manufacture of this equipment as well as a set of boilers for the Sea Wolf itself.

We have begun construction of a new building at our Chattanooga plant (see upper picture caption) to house special facilities for nuclear work. Already on the site is a 15,000,000 volt betatron for fast X-raying of thick plate and welds. We are also building a wharf on our Tennessee River frontage which will be equipped to handle reactor vessels weighing several hundred tons, permitting water shipment of vessels too heavy for rail or highway. This program is scheduled for completion early next year.

Our already extensive research and development program has recently been augmented by an agreement with the AEC covering design and evaluation studies of large reactors for power stations, small reactors for special application, design of reactor fuel elements and development of fuel element fabrication processes.

* * *

Thus is Combustion preparing itself to participate significantly in the challenging task of applying nuclear fission to the power needs of the future.

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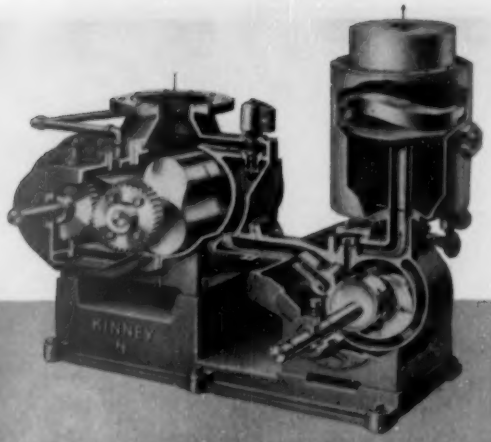

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Model KC-5	½ HP Compound Pump	4.9 CFM
Model KC-15	1 HP Compound Pump	15.2 CFM
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Model KS-13	½ HP Single Stage Simplex Pump	13.0 CFM
Model KS-27	1½ HP Single Stage Simplex Pump	27.0 CFM
MECHANICAL BOOSTER Model KMB-1200	15 HP Two Stage Pump at 1 micron	760 CFM
Model KS-47	2 HP Single Stage Simplex Pump	46.8 CFM
Model KDH-130	5 HP Single Stage Duplex Pump	131 CFM
Model KD-220	10 HP Single Stage Duplex Pump	218 CFM
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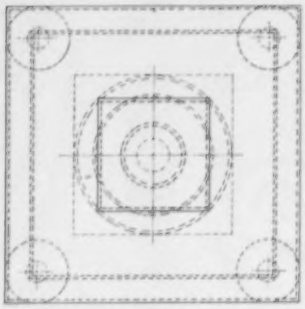

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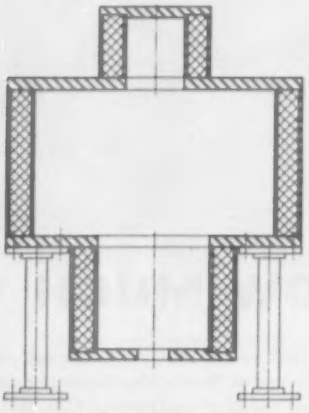

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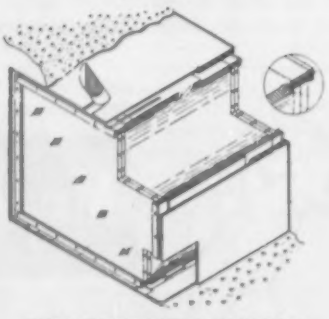

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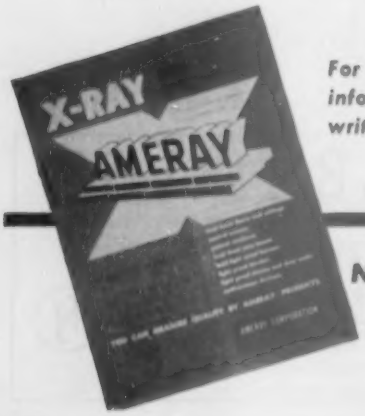

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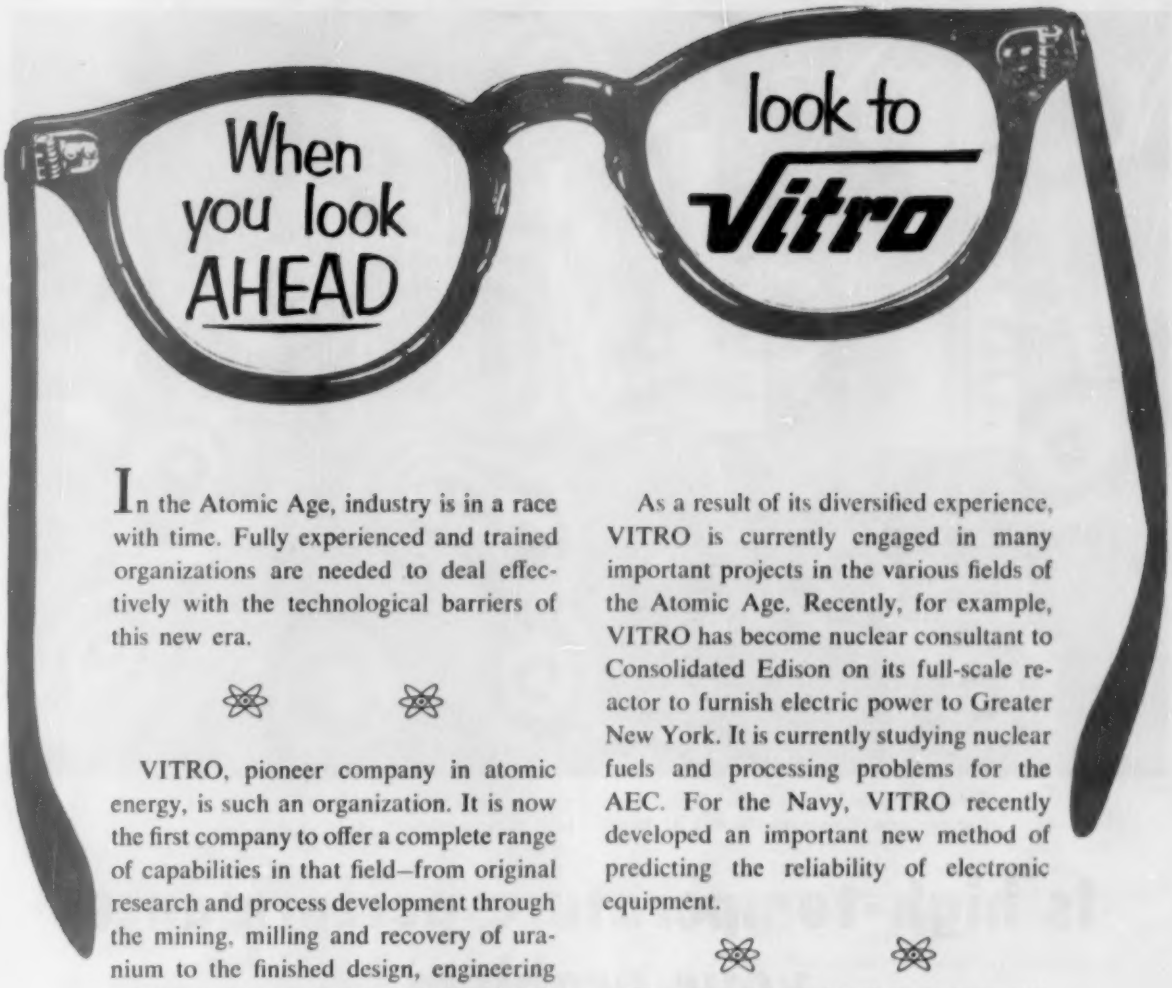

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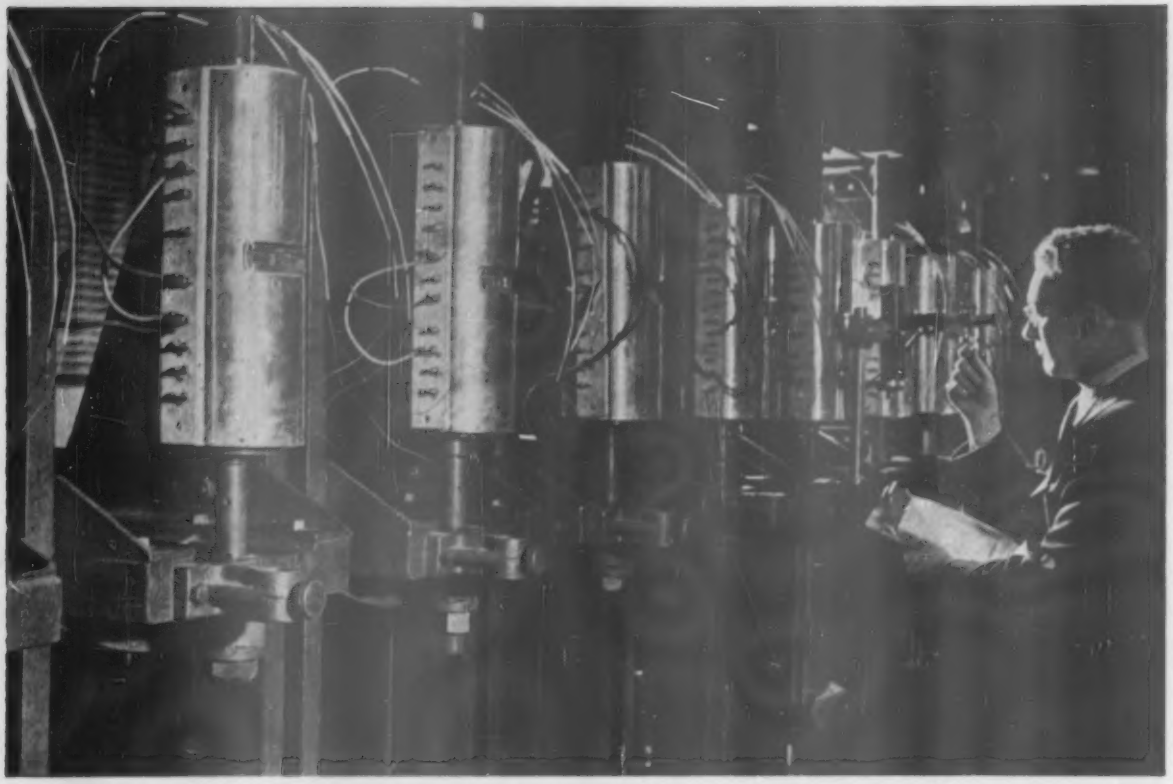

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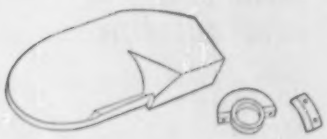

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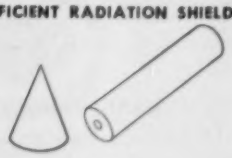

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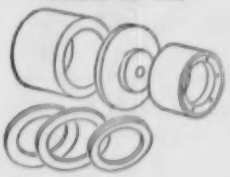

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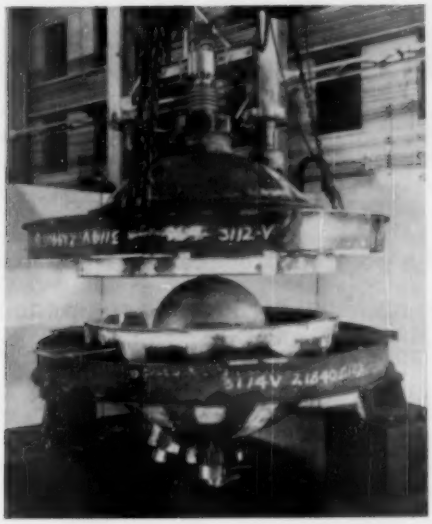

HOMOGENEOUS REACTOR TEST will use zirconium-alloy core tank seen between halves of pressure vessel to be sealed by girth weld. Core solution will enter at bottom center, exit through expansion bellows and nozzle at top center. Blanket fluid will enter via side nozzle and leave through side nozzles on top

Engineering and Construction of Nuclear Power Plants

Construction picture above shows the core of HRT-1, a prototype power reactor scheduled to operate initially at 5 Mw in 1956. Rather than being primarily a nuclear experiment like its predecessor, HRE, it is to determine long-term reliability and ease of underwater maintenance.

Typical of reactor construction at the present time, this development model is being built by industry (Newport News Shipbuilding and Dry Dock) for operation by a contractor (Union Carbide and Carbon) at a government installation (Atomic Energy Commission's Oak Ridge National Laboratory). ORNL designed the reactor.

Surging industrial interest in nuclear power plants is changing this pattern. The expansion and diffusion of effort requires practical data on engineering and construction. This special report brings together a big piece of the needed information and suggests both general and specific problems and solutions.

A NUCLEONICS Special Report

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Control-Rod Mechanisms . . . . page 48

How to Load Solid-Fuel Reactors . . . page 52

Designing and Building Shields . . . . . page 56

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Core Construction . . . page 70

Site Selection and Plant Layout

Here's how to go about choosing a site for a nuclear power plant—and how to place the components. Safety and waste disposal provisions are major considerations in both operations. Layout variations are given for six types of reactors

By S. M. STOLLER, *Vitro Corporation of America, New York, N. Y.*

ALL TYPES OF POWER REACTORS have common plant layout and site selection problems as well as having special problems peculiar to each type. Certain generalities can be made concerning economic limits, operating conditions, plant function, size, and site. These factors play key roles in site selection and plant layout.

Economic limits. A commercial nuclear plant must produce power competitively with conventionally fueled facilities located in the same area. Thus, site and layout decisions must be made to minimize capital and operating costs, while permitting consistently safe operation.

Operating conditions. Because of the high capital cost of a nuclear plant, power costs can be cut only by taking advantage of its low operating costs by using it as a base-load plant rather than only intermittently at peak loads. Thus, it must be stable and safe with minimum downtime and also must be capable of taking the normal variations in load experienced by base plants.

Function. The nuclear plant in the United States will be part of an established utility grid feeding power to expanding markets. Greatest demands apparently are from large industrial and residential areas with lesser demands from farm and other rural areas. Best use of nuclear power in other countries can be made in power-short nations with existing industry or strong raw material reserves.

Size. Design evaluations dictate plants to deliver between 60,000 and 200,000 kilowatts of commercial electric power. Smaller-sized pilot-model plants, mainly in the range of 1–10 Mw electric output, currently are receiving major emphasis in the U. S. Atomic Energy Commission's power reactor development program (NU, May '54, p. 72), but large plants will be most economically feasible for producing commercial power.

CHOOSING A SITE

Because of the high cost of power transmission, fulfilling power demands in highly industrialized areas, where much of the expanding markets for power exist, precludes isolation of the power plant on huge reservations in unpopulated zones. Plant locations here are considered close to populated areas, and site requirements should be considered only in this context.

Just as for conventional plants, the site for a nuclear power plant must have good-quality condenser water and boiler feedwater. Also it should have: a nearby source of labor; accessibility by public conveyance; good equipment-foundation conditions; good topographical features as regards clearing, leveling, drainage, and flood conditions. Besides these general requirements, safety and waste disposal are special site considerations that apply to nuclear plants.

Safety

Proper design provides a nuclear power plant with a safe reactor. As in any major operating equipment, provisions are made to assure maximum reliability of all reactor components, and fail-safe devices correct for possible operator errors or misjudgements.

An interlocking control system shuts the reactor down in the event of abnormal signals. Acts of God, such as flash floods and earthquakes, also are considered in the design. Prevailing meteorological and hydrological conditions of the site are evaluated with respect to upsetting normal plant operation.

As in any industrial operation, the possibility of affecting the surrounding area with a catastrophe does exist. But the penalty for a nuclear-reactor incident is greater because of the possibility of contamination by radioactivity. In the event of any credible combination of failures or external disturbances, either accidental or deliberate, a second line of defense is provided to prevent contamination of adjacent areas or endangering nearby personnel.

Containment. Radioactive products released by a nuclear incident would be contained by a gas-tight housing built as part of the reactor. Depending on reactor type, this enclosure can be of various forms and might enclose the reactor and other principal components of the primary loop individually within the individual shield compartments, or collectively around the entire primary plant. The type of containment and the details of its connection so that it is truly isolated from the surroundings are a major design and cost consider-

ation in nuclear power plant design. These factors must be studied in detail before AEC approval can be expected.

The type of reactor also has a major effect on the safety provisions. For research reactors operating at comparatively low power levels, building containment is adequate to prevent dispersion of fission products. Examples of this type of approach are the Sodium Reactor Experiment at Santa Susana, California, and the University of Michigan research reactor.

However, for large reactor power plants, current emphasis is on providing foolproof containments. The SIR-Mark A sphere at West Milton, New York, the cylindrical enclosure vessels used at the Duquesne Power and Light Co. plant near Shippingport, Pennsylvania, and similar vessels proposed for the Consolidated Edison plant near Peekskill, New York, are examples of today's approach to power-reactor safety.

Any design must be completely foolproof. Before AEC will grant approval to erect a plant in a populated area, the applicant must describe all credible calamites and how he will control spread of radioactive material.

It is interesting to note differences in cost between the exclusion-area and containment approaches to safety. Use of the "Reactor Safeguard Committee" formula, (NU, March '54, p. 75; April '54, p. 78) for a simple case yields an exclusion area of 70,000 acres for a 350-Mw reactor. At $1,000/acre for a site in a heavily industrialized area, land alone is $70-million. Large reactor containments would cost about $1–4-million, depending on reactor power, and could be placed on sites costing less than $1-million (640 acres at $1,000/acre = $640,000.)

Waste Disposal

Planning for disposal of wastes from a nuclear power plant is important in site selection. Various types of wastes can be considered by frequency of occurrence.

Continuous wastes. By nature of the requirement for constant disposal, these wastes are of low-level radioactivity. In a wholly or partially air-cooled reactor, continuous discharge of coolant takes place; meteorological conditions must be suitable for year-round reactor operation. In any nuclear plant, ventilation air always must be dispersed adequately to preclude shutdown under adverse weather conditions.

Periodic wastes. High-activity wastes, which are disposed of periodically, contain fission products or long-lived high-energy gamma emitters. Used fuel elements, filters, ion beds, and miscellaneous replacement parts containing high-activity materials are handled and disposed of with considerable care. Lower-activity wastes, such as the primary coolant from a water-cooled reactor or liquids used in operational tests or cleaning, have predominately short-lived activities and require only short-time retention before being returned to a water course.

Since in most designs the amount of burnup is quite small when the fuel is removed (because of radiation damage and buildup of fission products), much fissionable material is recovered by reprocessing. Systems such as the aqueous-homogeneous and liquid-metal-fuel reactors probably will process fuel radiochemically on the site. The large fuel inventories and short cycles of fast-breeder plants may cause them to include such reprocessing provisions. In these cases, provision must be made for on-site disposal of reprocessing wastes, which include fission products and chemical ventilation air.

ENGINEERING and CONSTRUCTION of NUCLEAR POWER PLANTS 1

Other reactors, such as the solid-fuel thermal types, probably will ship their irradiated fuel elements to an off-site reprocessing facility. The cost of shipping irradiated fuel elements to the reprocessing site is primarily a function of the ton-mile cost of transporting the large amounts of lead shielding required. Thus, it varies with distance, mode of transportation, amount of fuel, activity level, and time between shipments. These costs must be calculated specifically for each fuel system, but they generally will be 0.05–0.1 mills/kwh for a central-station power plant.

Catastrophic wastes. Radioactive wastes released by any catastrophies associated either with reactor malfunction or mistake in operation of the facilities must be contained within the site. Containment vessels are provided to prevent dispersion of radio-

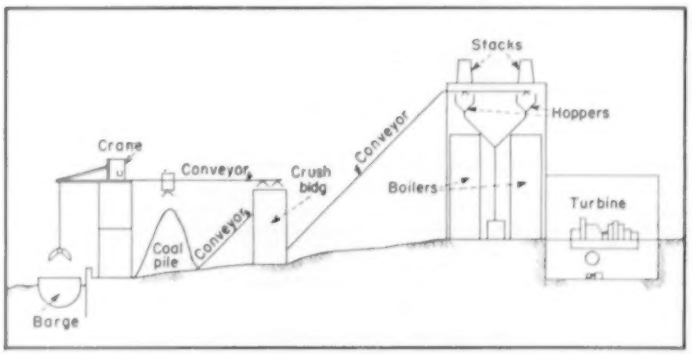


FIG. 1. Coal-fired plant has a well-integrated layout for storing, handling, and preparing the fuel that ends up at the boiler building. Since a large quantity of fuel is handled, the system is rather extensive

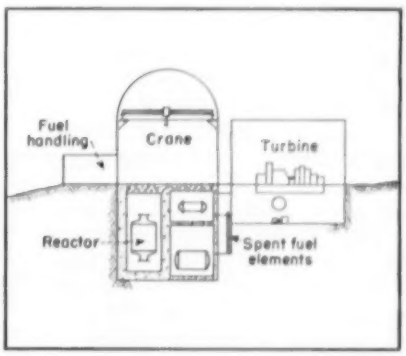


FIG. 2. For most nuclear plants, fuel is delivered ready for use. Relatively small area is needed for handling

active gas following any conceivable reactor incident.

Geology, subsoil conditions, ground and surface water movement, and earthquake frequency must be considered as they affect the malfunction of radioactive operations external to the containment vessels. Retention tanks, fuel storage, river cooling water passing through heat exchangers containing radioactive fluids, radioactive waste containers, and other auxiliary facilities must be properly designed and located on the site to prevent contamination of the surrounding area.

In the original design of the plant, no permanent facilities need be provided for storing the large quantities of radioactive waste that might be given off in an incident. When and if any catastrophe occurs, a major shutdown would be required; thus, decisions on specific storage requirements can best wait until the extent of the accident is known. For a very small cost at the plant-design stage, sizable future savings can be effected if provisions are included to simplify decontamination of the facility after an incident. These provisions might include: a means to connect to new storage facilities, carefully selected building surface coatings, and a layout that permits efficient major decontamination.

PLANT LAYOUT

Figures 1 and 2 show some major layout differences between nuclear and conventional power plants. For a plant using a homogeneous reactor, a feed makeup system is used. In addition to the common layout problems to be discussed in the following paragraphs, each type of reactor entails special factors as shown in the table.

Handling used fuel. Disposal of ashes from a coal-burning plant is a nuisance and sometimes is inconvenient, but it is relatively simple compared to the elaborate precautions involved in disposing of spent fuel from a nuclear power plant. After irradiation in the reactor, the spent elements are taken in a shielded coffin to a storage facility where their radioactivity decays. Cooling is provided to remove heat generated by the decaying fission products. The configuration of the storage facility prevents accidental accumulation of a critical mass of fissionable material, and the entire facility is shielded.

After their radioactivity decays sufficiently, the elements can be transported to the reprocessing plant. Facilities must be provided to load coffins remotely on motor or rail carriers (in most cases, these coffins will differ from those used to unload the

Special Layout Considerations

Reactor type	Reactor vessel
PRESSURIZED WATER. Fission heat removed from core by water pressurized to prevent boiling generates steam in low-pressure boiler.	In watertight shielded compartment separate from other parts of system so that compartment can be flooded for fuel changes or maintenance.
BOILING WATER. Fission heat forms steam in the core.	In separate shielded compartment either above or below grade. Pressure can be lower than in pressurized-water reactor of same output.
AQUEOUS HOMOGENEOUS.† Heat from aqueous solution or slurry of fuel and moderator circulating from core forms steam in boilers. Slow neutrons from core breed U^{233} fuel in Th^{232} blanket.	In same compartment as auxiliary high-pressure equipment and main heat exchangers. Blanket is at same pressure as core so as to neutralize stresses on core vessel.
FAST BREEDER. Heat from fission by fast neutrons is passed by Na coolant through intermediate coolant cycle‡ to boilers. Fast neutrons escaping core breed new fuel (Pu^{239}) in blanket (U^{238}).	In enclosed shield compartment separate from intermediate heat exchangers and steam generators. Atmospheric pressure satisfactory.
SODIUM GRAPHITE. Na or an alkali-metal eutectic takes high-temperature heat from graphite-moderated core to intermediate heat exchanger.	In enclosed shield compartment separate from intermediate heat exchangers and steam generators. Atmospheric pressure satisfactory.
GAS COOLED. Pressurized gas takes heat from fuel to boilers.	High pressure and high temperature required for efficient heat transfer.

* To limit spread of radioactive products in case of power-surge incident. † This type involves continuous removal of gaseous and solid fission products and requires shielded equipment to separate the gases, recombine dissociated water vapor, and remove solids. ‡ To prevent radioactivity from getting to power loop. ¶Storage facilities are provided for expensive inert gases when system coolant pressure is reduced for maintenance. So far, gas turbines have been limited to about 20 Mw; larger plants would use multiple turbine installations.

for Six Types of Reactors

Circuit layout	Piping system	Containment*
Boiler is above reactor so natural circulation can occur if pumps fail. Boiler-turbine distance is short for best use of low-pressure saturated steam. Since steam is not radioactive, direct-fired superheaters easily can be used to improve turbine output.	To retain pressure and prevent leakage of radioactive water, minimize closures. Since corrosion by hot water dictates use of thick stainless-steel pipes, arrange components to optimize piping cost consistent with thermal expansion requirements.	Must provide for release of energy in pressurized coolant in event of system failure. Container need include only primary system.
Steam drums in core compartment. Turbine, shielded during operation because steam is radioactive, can be flushed after shutdown and maintained directly.	Pressure is less than in primary circuit of pressurized water reactor of same output. Turbine is in same compartment as reactor, thus piping run is minimum.	Turbine must not leak radioactive coolant. Because container must include turbine, pressuretight building such as sphere at West Milton seems most practical.
Heat from blanket (about 17% of total) is transferred through separate heat exchange system. Chemical separations take place in side stream outside primary container.	Since extreme tightness of primary circuit is needed because it contains fission products, there are few joints, and bends are used rather than fittings.	Complicated because even a strictly mechanical failure in primary loop releases fission products. Blanket is contained also.
High-temperature system requires careful design of components and layout to prevent leaks caused by thermal expansion.	Alkali-metal coolant must not contact water in steam cycle. Steam is generated at high pressure, thus length and arrangement of piping from boilers to turbine is not as critical as in water-cooled types.	Must be very stringent because of concentrated energy source, control difficulty, and need for very rapid control and safety devices required with fast reactor, but low-pressure reactor eases problem of containing a sudden release of energy.
High-temperature system requires careful design of components and layout to prevent leaks caused by thermal expansion.	Alkali-metal coolant must not contact water in steam cycle. Steam is generated at high pressure, thus length and arrangement of piping from boilers to turbine is not as critical as in water-cooled types.	Low-pressure reactor eases problem of containing a sudden release of energy.
Must be extremely well laid out because: high pumping power is required; design is at upper limits of physical properties.¶	Primary circuit must be shielded because of induced activity in coolant (except He) and corrosion products.	Closed-cycle system requires large enclosures to contain turbine and large reactor; sphere seems most practical shape.

reactor). Although fuel in nuclear plants is not changed frequently, good layout reduces the cost and time of shutdown. A similar purpose is served by careful design of openings in containment and reactor tanks and use of reliable charging and discharging methods and devices.

Placing components. Generally, the reactor and associated primary loop components are confined to one shielded area so that all other units can be maintained normally without regard to radiation hazard. All performance data from the shielded reactor is available outside the shield; and the reactor is controlled from a central room.

Personnel traffic through the plant is controlled to prevent spread of low-level radioactivity.‖

Careful control of ventilating-air movement prevents spread of contamination from radioactive to nonradioactive areas. —END

Water Supplies for Reactors

Here's how requirements for processing water for condenser cooling, boiler feed, and reactor cooling vary. Although reactor-cooling water must be of the highest purity, water for other circuits also requires careful treatment

By H. W. HUNTLEY and S. UNTERMYER
General Electric Company, Schenectady, N. Y.

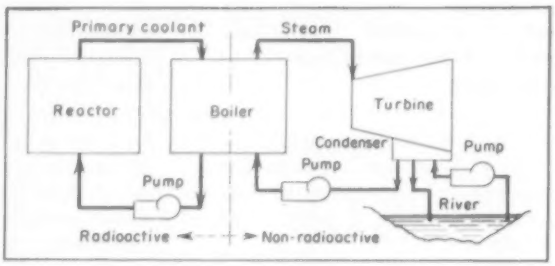


FIG. 1. Typical nuclear power cycle shows that the primary coolant system normally is the only one that becomes radioactive. Steam cycle and condenser cycle usually are not radioactive

AN AMPLE SUPPLY of cooling water is a prerequisite for any high-power reactor. The table shows that nuclear power plants presently have lower thermal efficiencies than modern steam plants and require more cooling water for the same electric output. Because of their lower thermal efficiencies, reactor plants can be expected to be much more sensitive to the cost of cooling-water supply.

When adequate cooling-water supplies are not available, water requirements can be reduced through use of spray ponds or cooling towers, as indicated in the last column of the table. Such measures are rarely justified by economics, and use of evaporative cooling generally is confined to experimental installations, where it usually produces water temperatures 5–10° F higher than the local wet bulb.

Figure 1 shows that in a typical nuclear power plant there may be three separate water systems—the condenser cooling water, boiler feed water, and reactor cooling water. The cycle shown represents that for a pressurized-water reactor. A boiling-water reactor converts the primary coolant directly into steam. A liquid-metal-cooled reactor uses a metal or alloy, such as sodium, bismuth, or NaK, as primary coolant. In all of these, only the primary coolant is exposed to the radioactivity-inducing neutrons from the reactor. But the primary coolant of a homogeneous reactor contains a fuel solution from which delayed neutrons are emitted that may make the steam system slightly radioactive. The pressurized-water-reactor system shown typifies water-treatment procedures.

Cooling-Water Requirements for Power Plants of Various Efficiencies*

Net thermal efficiency (%)	*Heat rate* (*Btu/net kwh*)	*Increase in heat rate from 1 in. to 2 in. Hg* (%)	*Cooling-water flow for* $\Delta t = 50°$ *F* (*gph/kw*)	*Cooling-water flow for evaporative cooling* (*gph/kw*)
15	22,700	6	51	2.6
20	17,000	5	36	1.9
25	13,600	4	27	1.4
30	11,400	3	21	1.1
35	9,700	2½	17	0.9
40	8,500	2	14	0.7

* Approximate ranges of efficiencies for various plants are: 18–28% for pressurized-water reactors, 23–33% for boiling-water reactors, 25–35% for liquid-metal reactors, and 33–40% for conventional coal-fired plants.

Condenser Cooling Water

Since condenser circulating water for reactor systems normally does not become radioactive, it need be processed only sufficiently to avoid fouling pumps, piping, and heat-transfer surfaces. Treatment may involve filtration, algae control, coagulation, or softening (*1, 2, 3*).

The effluent should be monitored so as to detect any leakage of radioactive water into the condenser cooling system. However, the pressure differential normally would cause cooling water to leak into the condenser shell, so that occurrence of radioactivity in the condenser circulation system would require a series of extremely unlikely contingencies.

Boiler Feed Water

It is customary to maintain high standards of purity for boiler water in reactor plants. High purity is required to minimize scale formation in the highly radioactive boiler, and there is always a remote chance that the

boiler feed water might inadvertently enter the reactor.

Generally, resistivity is maintained at about 500,000 ohm/cm, and total solids are kept below 10 ppm. When mild-steel boilers are used, corrosion is reduced by lowering the oxygen content or by adding hydrogen. With stainless-steel boilers, chloride ion concentration must be minimized.

To meet these requirements, water in reactor plants is bled continuously from the boiler drum, cooled below 100° F so it can be filtered and deionized; then it is reheated to the operating temperature of the system (*3, 4, 5*).

Reactor Cooling Water

Water becomes radioactive when it passes through a reactor's neutron field. The radioactivity is due to: (a) the short-lived products of neutron capture by oxygen, and (b) activation of the impurities present in the water. Oxygen radioactivity causes water passed through a reactor to remain intensely radioactive for about 5 minutes. Thus, heavy shielding is required around heat exchangers and coolant pipes.

Treatment of water for the primary cooling system must meet all the usual purity standards for boiler water. In addition, those impurities that might result in residual radioactivity must be reduced to a bare minimum. Use of high-purity water reduces maintenance problems with primary-coolant pumps, piping, and heat exchangers. Cations of such materials as manganese, cobalt, or sodium must be removed because they produce energetic gamma rays. As a result of these stringent purity requirements, the quality of primary cooling water is maintained by continuous operation of an ion-exchange and filter system arranged as shown in either Fig. 2 or 3.

Repurification rate. One of the most important variables to be established in the design of a water purification plant is the repurification rate. Experience indicates that the great bulk of the radioactive material is removed during passage of water through an ion exchanger. Such units vary in size from a capacity to purify the system in one week up to a capacity to clean up the entire system in one hour. An economic balance should be achieved.

There are three general classes of radioactive contaminants: (a) corrosion products, (b) fission products, and (c) water impurities. For fission products and corrosion products from fuel cladding or tank walls, the radioactivity developed by corrosion products varies inversely with purification rate. But radioactivity of isotopes dissolved in the coolant entering the reactor varies inversely with the square of the purification rate.

Mixed- or separate-resin beds. Both mixed-bed resins and separate anion-cation-resin beds have been used. Simplicity of regeneration under remote control conditions favors use of separate beds. In many cases it may be advantageous to discard used ionic resins without regeneration. In this way, the ionic resins are used as a means of storing radioactive material in solid form. Since some resins can absorb up to 2 lb of ions per cubic foot, this method of storing radioactivity often may be more economical than storage of the liquid wastes resulting from the regeneration of the resin beds. Mixed-bed resins are preferred when regeneration is not used, as mixed beds produce the highest-quality water.

Since the radioactivity is concentrated by the ionic resins, monitors located near the demineralizer normally give accurate and early indications of fuel-element failures or unusual corrosion.

Distillation. Unlike ion exchangers, evaporative stills can economically handle accumulated radioactivity in grossly contaminated water and can concentrate the impurities into a small volume. Distillation is most useful for cleanup of a badly contaminated water system. After cleanup is completed, ionic resins maintain purity more conveniently and at lower cost.

FIG. 2 (right). Demineralizer in bypass stream from main coolant circuit purifies water. Unit handles intensely radioactive products. Since ion-exchange resins cannot operate at high temperature, water must be cooled before passing through demineralizer

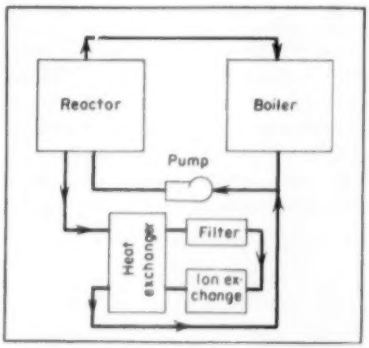
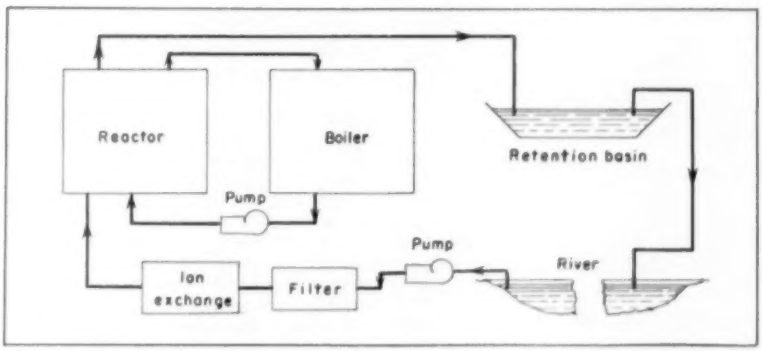


FIG. 3 (below). Demineralizer in a continuous makeup stream purifies water. Unit handles nonradioactive materials. But radioactive water is bled continuously, and a retention basin is needed to permit decay of radioactivity before returning water to river



BIBLIOGRAPHY

1. S. T. Powell, "Water Conditioning for Industry" (McGraw-Hill Book Co., Inc., New York, 1954)
2. B. N. Baker, "The Quest for Pure Water" (American Water Works Association, New York, 1948)
3. *Proc. Ann. Water Conf., Eng. Soc. West. Penn., 15th Ann. Conf.* (1954)
4. R. Kunin, R. J. Myers, "Ion Exchange Resins" (John Wiley & Sons, Inc., New York, 1951)
5. N. K. Hiester, R. C. Philips, "Ion Exchange," *Chem. Eng.* **61,** No. 10, 161 (1954)

Control-Rod Mechanisms

Here's how to design reactor control-rod drives including motors, position monitors, drive mechanisms, and quick return for safety. Four examples typical of actual reactors are illustrated and discussed

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Rods composed of fissionable, reflecting, or neutron-absorbing material are used to control the reactivity of nuclear power reactors (*1*). These rods must be positioned accurately to set power level, they must move at a certain rate to change power-level, and they must have provision for rapid action to shut down the reactor if safety demands. Drive mechanisms for these control rods are the subject of this article.

Drive design is strongly affected by the reactor type for which the control rod is intended. For example, power reactors cannot use the simple pivoted rod that is used in Argonne's CP-5 heavy-water-moderated research reactor. Rather, linear-motion control rods are required. For pressurized-water reactors the control sections proper weigh 50–100 lb; with drive rods included the weight is 100–300 lb. Ambient temperatures and pressures are 400–500° F and 300–2,000 psi, and drive-rod seals are required if the drive mechanism is to be located outside the pressure container. On the other hand, liquid-metal-cooled reactors have a simpler sealing problem (usually helium gas at slightly above atmospheric pressure is maintained over the liquid-metal coolant), but rods can weigh several hundred pounds if reflector control is used.

Drive Specifications

Four general drive specifications that reflect the underlying reactor-control requirements are:

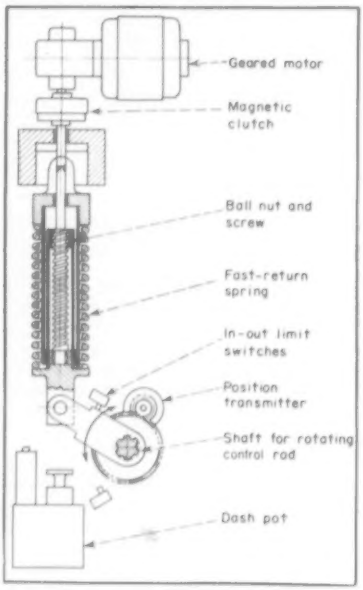
1. Speed. The mechanism must move the rod in a direction of increase or decrease of reactivity at $10^{-4}\delta k$ per sec at that position in the core where the rod is most effective. The drive speed in inches per second can be estimated from

$$\text{drive speed} = \frac{L}{FK} \times 10^{-4} \quad \text{[in./sec]} \qquad (1)$$

where L = core length in inches, K = total rod effectiveness in δk, F = a factor which reflects the rod effectiveness at the operating point as compared with the average effect. Lacking a more

1. Drive for Rotating Control Rod

ADVANTAGES: Continuous application of return force from both gravity and spring, position indication by both synchro and limit switches, and no time lost resetting before motor can re-engage



Rotating neutron-absorbing rod attached to this drive rests diagonally between core elements and is removed by pivoting upward to a horizontal position above core. Rotating lead screw draws ball nut upward, raising rod arm and compressing fast-return spring. Motor rating is 40-in.-lb torque at 9 watts d-c. In typical installation motor gear-head ratio was 850:1, thread lead was $\frac{3}{16}$ in. per revolution, and fully compressed spring gave 1,000-lb force. Alignment is provided by universal joint. Synchro position transmitter is attached directly to rotating shaft along with a set of cams that operate limit switches as travel progresses. For quick return clutch is released in about 0.01 sec allowing spring to drive ball nut backward. Quick-return time was 0.25–0.45 sec

definite value use $F = 4$. The factor 10^{-4} has dimensions sec^{-1}. Controlled speed variation of at least 4:1 is desirable.

2. Positioning. The mechanism should be irreversible so that forces acting upon the rod cannot move the mechanism. Motors used to power the rod drive mechanism should have brakes to stop the drive within 0.2 sec after the power is turned off. Mechanical tolerances should provide position repeatability of $2 \times 10^{-5}\delta k$. Repeatability in inches can be computed from

$$\text{Repeatability} = \frac{2L}{FK} \times 10^{-5} \quad \text{[in.]}$$

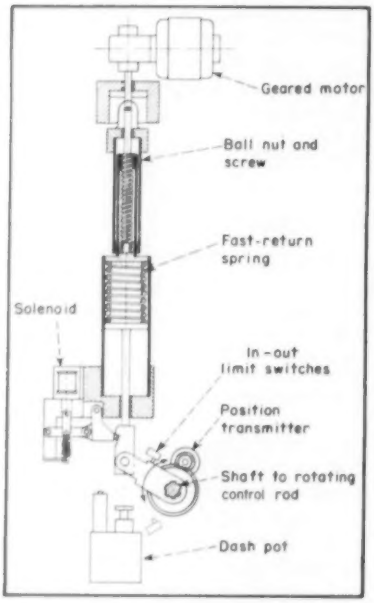
The symbols mean the same as Eq. 1.

3. Position indication. An essential part of the drive mechanism is a position pickup for use with a remote position indicator located at the reactor control console, such as a synchro transmitter and receiver pair. Accuracy of position indication should equal the position repeatability given above. Limit switches or equivalent indicators such as magnetic detector coils are required at least in the minimum-reactivity position. One or more intermediate and a maximum-reactivity position indicator are desirable.

4. Safety release. A stored-energy source such as gravity or a compressed spring must act on the drive rod throughout the stroke that reduces reactivity. A magnetic clutch or latch should be inserted between the drive mechanism and the rod which, when de-energized, allows the rod to move freely under the effect of this stored energy source at a net acceleration not less than 0.9 gravity. Friction in guide bearings and seals makes depending entirely upon gravity undesirable. Where rod travel is several feet a driving force such as a pneumatic piston is used. Where application of a return force throughout full travel is impractical a compressed spring, several inches long, is used to give the rod an initial acceleration of about five times gravity. Typical values obtained for rapid-motion rod stroke vary from 0.3 to 0.6 sec. Deceleration should take place in not more than the last 10% of the rod stroke.

2. Solenoid-Latched Rotary Drive

ADVANTAGES: Same as Fig. 1 except that after quick-return stroke several minutes are required to relatch. This disadvantage is minor compared to gain from reduction in inertia and friction



Rod is solenoid latched against ball-nut drive. Latch release (in about 0.025 sec) returns rod. Since rod falls free of mechanism quick return has very little inertia or friction. Solenoid developed 75 lb to hold 1,000-lb force of compressed spring. Slight out-of-line arrangement of latch linkage at point where solenoid is attached makes force from rod-return spring act against solenoid and provides a release force even if latch spring breaks. Quick-return time was less than 0.17 sec. Note how separation of normal and fast-return motions eliminates need for magnetic clutch. Dash pot damps out motion of fast return at end of fast-return stroke. Limit switches indicate extremes of motion. Position transmitter provides continuous indication of angle of control-rod shaft

Design Considerations

Mechanical design principals for control-rod-drive mechanisms are the same as for any machine and are well known. The basic mechanisms used to drive control rods are rack and pinion, lead screw and nut, ball-bearing screw jack, and hydraulic or pneumatic piston. These devices fall under a general classification of mechanical jacks having infinitely small steps. Mechanical jacks with finite steps can be used on power reactors, especially boiling-water reactors, where the rod positioning requirements given above can be relaxed. Step movements, however, should be no larger than $10^{-4}\delta k$ each and preferably $\frac{1}{2}$ or $\frac{1}{3}$ of that.

In designing control-rod drives the following points should be given detailed consideration:

Drive rod. Control-rod mechanisms are installed 10–20 ft from the reactor core to provide neutron shielding, facilitate cooling and lubrication, and give mechanical clearance for other parts of the reactor assembly. A drive rod is needed to connect drive mechanism and control rod in the reactor core. It must withstand the forces developed during rapid reactivity reduction, especially the force of deceleration. Joints in this section are necessary for maintenance disassembly and assembly. Threaded joints are desirable if the joined sections can be guided so that they cannot twist loose. Pinned or flanged joints can be used. The drive rod should support the rod in the core with the drive removed to make assembly possible. Joints between this support and the rod proper should be welded.

Mechanism travel. The ultimate mechanical limits of the drive mechanism should allow about 1–5% greater travel than the specified rod stroke. The exact drive-stroke limits can be set after installation with reference to the control rod position in the core by adjusting limit switches in the motor power circuit. Adjustable mechanical stops at travel limits can be used for piston drives.

Mechanism spacing. Typical power-producing nuclear reactors re-

quire a number of control rods spaced, typically, on 4–12-in. centers. Mechanisms should be spaced far enough apart for maintenance and replacement operations. Often the location of control rods in the core must be determined by an engineering compromise that considers control-rod-drive clearances. Mechanisms of the types shown in Figs. 3 and 4, where used on power reactors, require a minimum space of about 6 in. Experience has shown that drive spacings less than 12 in. on center make maintenance difficult.

Motors. Any type of motor, pneumatic, hydraulic, or electric, can be used on a rod drive but the easiest to apply is an electric motor.

Direct-current motors offer two advantages: simple speed control by armature voltage, and dynamic braking by shorting armature terminals. These motors are operated with the field continuously energized, control switches being used in the armature circuit only. They are easily incorporated in feed-back control systems because of the adjustable speed feature which, in a control system, corresponds to changing the gain of a servomechanism. The chief disadvantages are brush maintenance and the necessity of providing d-c power.

Two-phase a-c motors also provide the advantage of speed control and are especially suitable for feed-back control schemes. In addition, commercial two-phase servo motors offer a high torque-to-armature-inertia ratio that makes a mechanical brake unnecessary if the gear ratio between motor and drive is high or if a reasonable friction loss is present in the mechanism gearing. This type of motor has been applied on experimental-reactor rod drives where power requirements are less than $\frac{1}{4}$ hp. On pressurized power reactors the drives require larger motors and three-phase motors are more economical. Speed variation for three-phase motors is costly and, therefore, is not provided. Uncertainties in rod speed requirement are covered by easily changed speed reducers between motor and mechanism; thus the final rod speed can be set after the effectiveness of the rods has been determined experimentally. Three-phase a-c motors have a low torque-to-inertia ratio as compared with two-phase motors so that a solenoid-operated friction brake on the motor shaft must be used to stop the rod quickly.

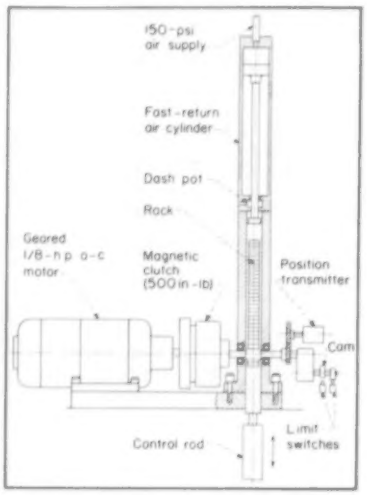
The chief advantage of both types of a-c motors is that the maximum speed is fixed by the line frequency and not by applied voltage. This speed limitation makes the rod drive safer. Other details about motors may be found in an earlier article in NUCLEONICS (*1*).

Position measurement. Position measurement is so important to safe reactor operation that both limit switches and continuous position indicators should be attached to the rod to insure that some indication will always be available. In an emergency it is very important to know at least roughly where the rods are.

In attaching a pickup unit for rod position the most direct method is preferred, for example, providing a rotating shaft geared directly to the rod drive shaft. The transmitter of a synchro pair attached to this rotating shaft should be geared so that 350-deg or less rotation at the transmitter represents full rod stroke thus eliminating ambiguity at the receiver. The accuracy of position indication for this arrangement for example is, $\pm\frac{1}{350}$th of the rod stroke. This is normally not accurate enough for reactor operation and a second fine-position transmitter is used which turns 360 deg for each 1–10 in. of rod movemen . Provision should be made on the coarse position shaft to install several cams to operate limit switches. Control-circuit interlocking often requires switches operated at both travel limits and at some intermediate rod positions. It is advisable to provide for a total of at least four cams to operate precision snap-action switches rated 5–15-amp a-c or $\frac{1}{4}$–$\frac{3}{4}$-amp d-c at 110 volts.

3. Linear Drive, Magnetic Clutch

ADVANTAGES: Stored-energy source in addition to gravity and continuous position indication by synchro pair and limit switches are provided. Drive is adaptable to pushing rods up out of core from underneath. Fast-return force is then from three sources: gravity, air pressure, and pressure inside reactor container. No pressure-balancing cylinder is needed then, but motor size must be increased to overcome force due to container pressure



This linear drive uses rack and pinion. Motor is $\frac{1}{8}$-hp 2-phase a-c. Magnetic clutch developing 500-in.-lb torque releases drive for quick-return stroke that is completed in 0.3 sec

Testing Control-Rod Drives

Repairing or replacing rod drives after the reactor has operated is always undesirable; therefore, a test program is arranged prior to operating the reactor. Usually a full-size prototype is built and tested under temperature and pressure conditions. This is especially necessary if the design is new or if a new assembly of standard units is employed. A suggested test consists of 500–1,000 cycles through the rod stroke with an equal number of quick-return operations. Observations of wear or galling should be made and the time for quick return measured at intervals of 50–100 strokes. Frequently the mechanism is tested under adverse or misuse conditions such as with no lubricant, dirt and grit on moving parts, at temperatures above those expected in operation, and with shock absorbers inoperative.

After installation on the reactor, rods should be cycled several hundred times while fast return is timed, dash-pot action observed and adjusted, and limit switches and position indicators are thoroughly checked out. Thoroughness on this point cannot be overstressed since rods are reactor protective devices and proper operation when required will prevent reactor-core damage.

One type of mechanism has been shown in Fig. 4 for which the coarse position transmitter is not necessary. The drive rod is forced away from the drive for rapid return and synchro pairs can easily follow the relatively slow movement of the motor-driven stop. Cams are used as above for control of the variable stop position but in addition a limit switch must be operated by the rod at the "in" position and another must be used to show that the rod is in contact with the stop. Between these two positions no rod-position information is obtained. For good design practice, indicating switches should be spaced about every 20% of the rod stroke for indication during the fast return stroke.

Magnetic latches. Magnetic latching of the mechanism with the current "on" to hold the rod in position provides desirable fail-safe rod release. By employing a mechanical advantage as shown in Fig. 2, a solenoid latch with a holding force of 40–80 lb can be used for rods weighing up to 1,000 lb. Roller latches reduce friction and d-c magnets provide more certain holding force. The latch linkage should be designed so that return force on rod acts to open latch even if latch spring should fail.

Release times for magnets and latches range from 0.025 to 0.075 sec in most applications.

Drive Seals

In special cases where leakage from a pressurized-water reactor is to be held virtually to zero, the entire drive mechanism (gears, ball-nut jack, dash pot, position indicators, etc.) is sometimes located *inside* the pressurized container. Canned-rotor motors and canned-rotor synchro transmitters with electrical windings outside the pressure-resisting enclosure are used to supply power and indicate rod position. This method is costly and a preferred method is to place a pressure seal on the drive. Seals on rod drives are of the general types, shown in the Mechanical Engineer's Handbook (*3*), called rod or plunger packings and shaft packing.

Both rotary-motion or linear-motion seals can be used and both provide reliable service if installed according to manufacturer's recommendations. By using a linear seal the entire mechanism can be placed outside the pressure shell where maintenance can be performed on the rack and pinion gears or lead-screw assembly, and where the dash pot can be adjusted. This undeniable advantage will serve to offset the fact that friction is relatively large, especially if a pressure-balancing system requiring two seals is used as in Fig. 4. For a rotary-sealed drive a rack and pinion similar to that in Fig. 3 is used, the seal being located between magnetic clutch and pinion gear. The air cylinder shown can be replaced with either a linear or a wound spring arranged to supply the stored energy for rod return. With a rotary-motion shaft seal friction is very low which makes the rapid return of the rod more certain and reduces drive-motor power requirements. Servicing the parts of the operating mechanism beyond the seal point is difficult.

Liquid-metal-cooled power reactors have helium atmospheres at relatively low pressures. Commercially available* bellows seals can be used for pressures up to 150 psi and for rod strokes up to 14 in. Compression of bellows must be held to about 30% of the extended length to avoid shortening its life.

At pressures above 150 psi, shaft packing of the complete circle type is used for both rotary and linear motion. Ordinary materials can be used, as in any seal application, since damaging radiation is low at their location several feet from the core proper.

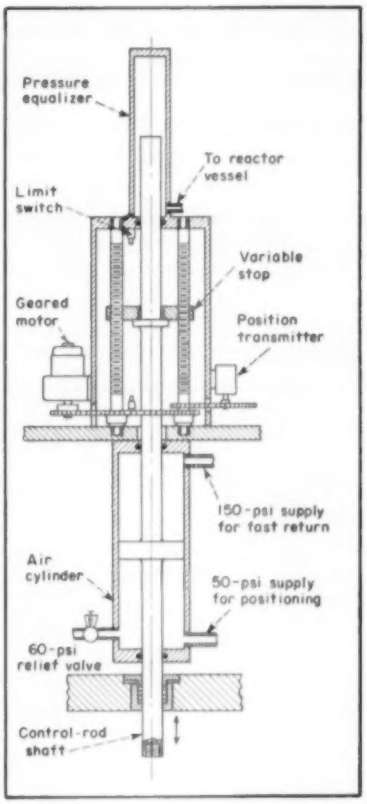
The floating-metal-ring seal has proven very practical and very little wear or galling of the shaft is experienced. Leakage rates are 0.2–1 gal/min at pressures up to about 1,000 psi because of the pressure-breakdown principal of this seal. To hold net leakage to zero an atmospheric seal is added and a small vacuum is maintained between the pressure and atmospheric seals where the leaking fluid is collected and then reinjected into the system.

* * *

The drive of Fig. 4 was designed by H. V. Lichtenberger. The other drives were designed by J. J. Dickson, who also supplied the design and test data given in parts of the text.

4. Movable-Stop Pneumatic Drive

ADVANTAGES: Should piston fail, motor-driven stop follows up and slowly forces rod into minimum-reactivity position. Lack of position indication during return stroke can be remedied with limit switches every 2–3 in. As in Fig. 2 several minutes are required for stop to re-contact rod after fast return. As with Fig. 3, drive adapts to pushing from below



Pneumatic or hydraulic drives are not generally capable of the positioning or "stand still" required of control rods. A ¼-hp gear motor, driving through pair of lead screws and nuts, moves variable stop against which drive rod is held by pneumatic force. Force due to pressure from inside reactor pressure vessel is balanced by pressure equalizer that connects back to it. During quick return, low-pressure end of cylinder vents through 60-psi spring-loaded relief valve. The 150-psi air is applied by operating solenoid valve in about 0.050 sec. Fast return was 0.2–0.3 sec for 2-ft stroke. Position indicator locates variable stop only. Limit switch on variable stop (not shown) is actuated when stop and rod touch; another is contacted when rod is fully down. If rod sticks during control operation, interlock applies quick-return air pressure

BIBLIOGRAPHY

1. R. L. Murray, J. W. Nestlie, NUCLEONICS **13**, No. 2, 18 (1955)
2. J. M. Harrer, NUCLEONICS **11**, No. 6, 39 (1953)
3. Lionel S. Marks, ed., "Mechanical Engineer's Handbook," Fifth Edition, p. 1,099 (McGraw-Hill Book Co., Inc., New York, 1951)

* Suppliers include Cook Electric, Chicago, Ill.; Flexonics, Maywood, Ill.; and Solar Aircraft, San Diego, Calif.

How to Load Solid-Fuel Reactors

Here, in terms of the operations required, is a description of equipment for loading power reactors—from the simple boat hook used for manual loading of pool-type reactors to the built-in, remotely operated, leakless systems for sodium reactors

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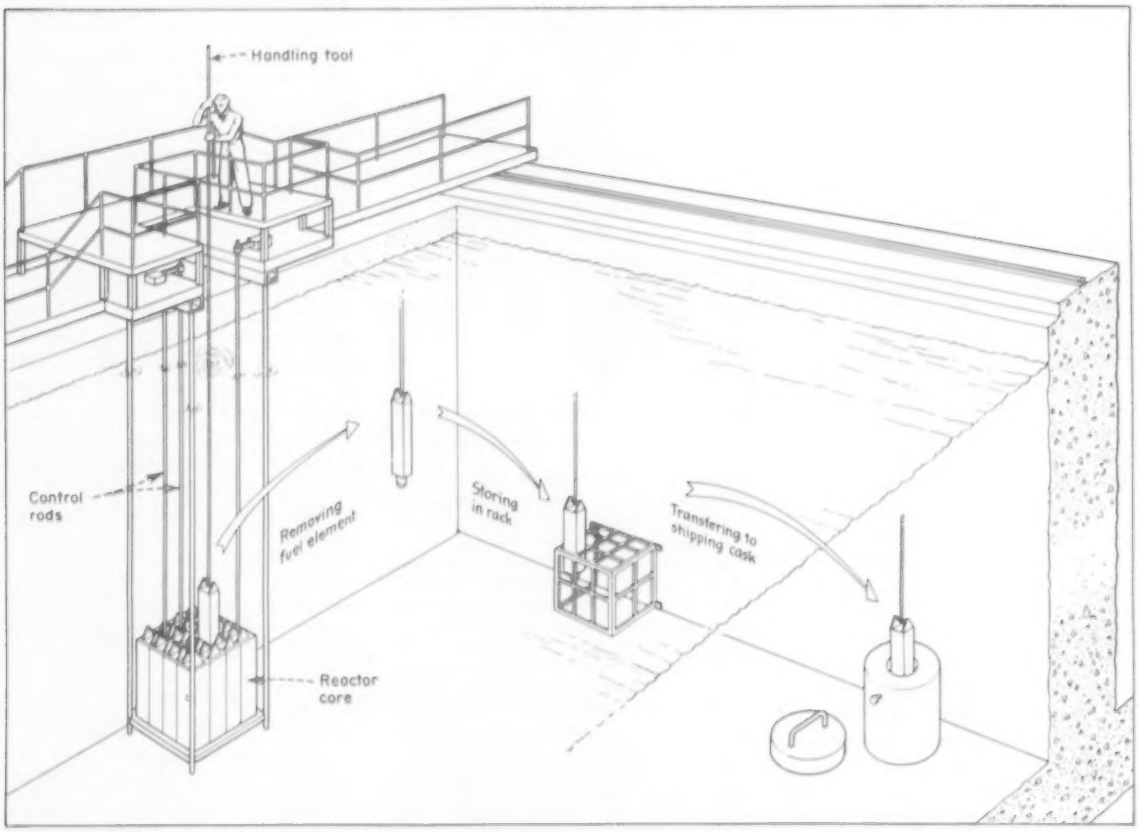
American Machine and Foundry Co., Greenwich, Connecticut

1. Small Reactors Are Refueled Manually



Unloading of pool-type reactor is by steps shown. (Fueling is by reverse process.) Overhead crane will lift shipping cask out of pool for shipment to separate processing plant. Low-power heavy-water or pressurized-water reactors can be loaded similarly. In some cases operator viewing through periscope and aided by hoist puts spent fuel element directly into shipping cask

NUCLEAR REACTORS must have their fuel supply replenished periodically. Fuel is removed and replaced on a cycle determined by the burnup of fissionable atoms, corrosion damage, and the buildup of fission products. Unlike the solid-fuel reactors considered here, liquid-fuel reactors of the homogeneous and liquid-metal-fuel class refuel and remove spent fuel on a continuous-flow basis. Process apparatus adds fresh fuel and removes fission products; fuel handling is a by-product of the over-all operating cycle.

In solid-fuel reactors, fuel is held in containers, usually called assemblies, and must be removed by a batch method. Ideally, solid-fuel handling equipment would load and unload the reactor without interrupting neutron production. Actually, many considerations prevent attaining the ideal. The foremost objection to refueling with solid fuel during reactor power operation is the possibility of creating unstable operating conditions by the addition of large amounts of reactivity.

Discussion of solid-fuel handling equipment will be presented in two reactor categories. These are: (a) small reactors (research and small power reactors), and (b) large reactors (power reactors of the pressurized-water and sodium-cooled types).

The discussion will not include fuel processing, although fuel handling devices are important there. Where necessary, hypothetical reactors embodying typical equipment are reproduced, rather than classified systems.

Small Reactors

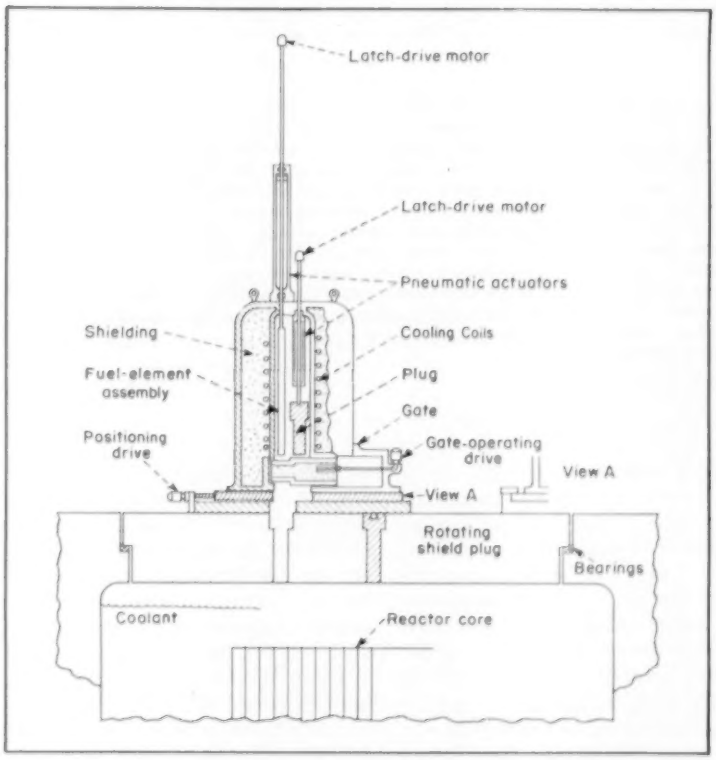
These are typified by the pool-type reactor, which, while not a power-producing reactor, graphically illustrates the fuel-handling techniques employed.

Pool-type reactors demand little of fuel-handling equipment (Fig. 1). Fuel-element assemblies mount in the core by engaging pilot plugs on their lower ends in holes in a base-plate grid. The elements dwell in the reactor core for prolonged periods; thus recharging time is not an important consideration. The reactor has an open top face covered by clear water, and the fuel element assemblies are small and light. Radiation level at the reactor bridge is tolerable to operators; therefore, manual loading and unloading with boat hooks is entirely suitable.

In a simple case such as this, the regulating and shim rod drives and fission-chamber drives and their connections to the reactor core may occupy the space above the core and tend to obstruct unloading and loading.

Manual refueling of small reactors appears simple. Nevertheless, the simplicity imposes rigid operating practices upon the reactor facility to replace the elaborate safety interlocks of semi-automatic and automatic systems. Operators must follow strict procedures, enforced and supervised by competent health-physics officers. Radiation at the operating position rather than mechanical feasibility or apparent convenience is the criterion upon which acceptability must be based.

2. Infrequently Loaded Reactors Use Cask-Type Machine



To refuel, plug above fuel element is removed by right-hand latching rod and drive. Cask is advanced to center handling rod over fuel element. Pneumatic actuator then advances and drive causes latch to engage. Fuel element is then withdrawn into cask. Fresh element, stored in cask, is inserted into core and plug is replaced. Shielding gate then closes entrance to cask and building crane carries it to processing area

A cask type refueling machine, Fig. 2, described later in the article, is used for some reactors of the CP-5 heavy-water type.

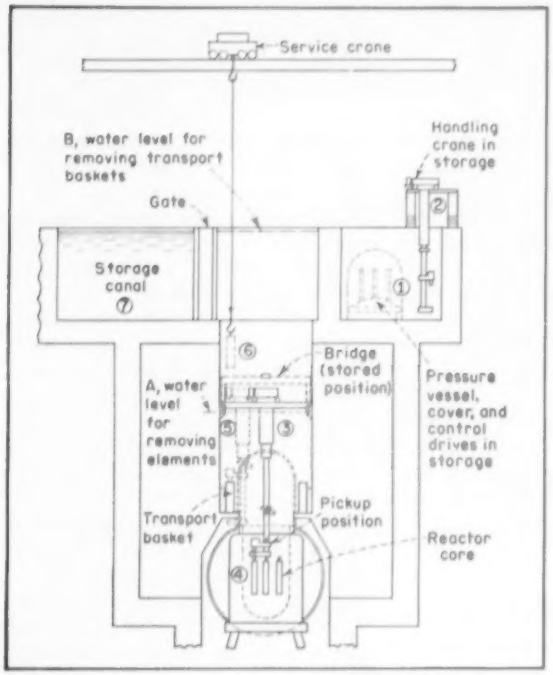
Large Power Reactors

The design of solid-fuel handling systems for large power reactors depends upon many factors: compartment layouts, building arrangement, containment scheme, interlocks, reactor-vessel design, fuel geometry, core design, coolant, frequency of refueling, shielding provided during refueling, and shape and quantity of elements other than fuel that need to be replaced.

A common practice is to investigate fuel-handling equipment after all other

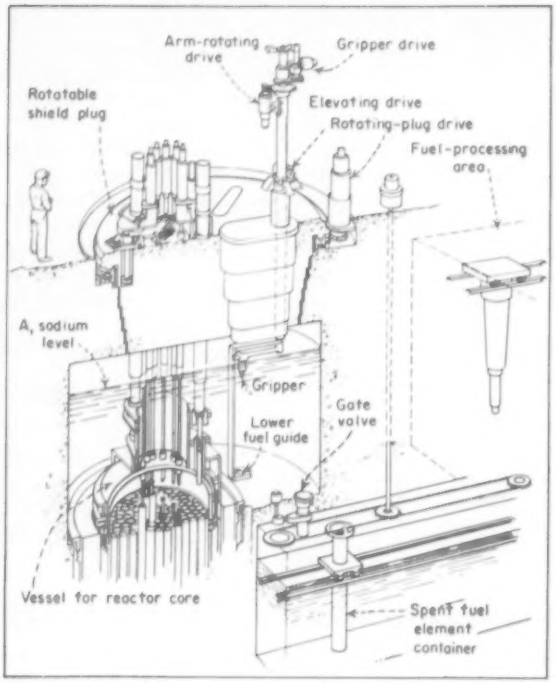
ENGINEERING and CONSTRUCTION of NUCLEAR POWER PLANTS **4**

3. Large Pressurized-Water Reactors Use Semiportable Remote Handling



To refuel, shielding and containment cover is removed and vessel flooded to level A. Then pressure cover is stored (1); handling crane (2) is lowered onto bridge in containment shaftway (3). Local operator, via periscope, locates latch at bottom of mast over check pins fixed to core structure. Indexing device that insures accurate alignment is zeroed and locked; then elements are extracted by operator at remote console. Mast is driven down and latches onto element assembly (4). (Guide holds down adjacent elements.) Unit is indexed over to transport basket (5) for temporary storage. This is later lifted (6) into storage canal (7) with water level at B, that of the canal. Fueling is by reverse process. After refueling, service crane stores handling crane in storage area

4. Sodium-Cooled Reactor Has Built-In Handling System



To refuel, control rods are first delatched and reactor-core cover disconnected and lifted. Shield plug is rotated to carry rotatable fuel-handler into position above core. Combined rotations can move crane over any fuel-element assembly. Power drive lowers gripper until it latches on; remote indicators tell operator when this occurs. Crane then raises element while guide prevents swinging and holds down adjacent elements. Raised crane is then rotated with plug and servo-positioned accurately over exit gate valve; valve leads to air-lock arrangement with reciprocating carriage for carrying fuel element to processing area. Carriage is driven by remotely controlled chain drive

reactor features are established. This practice results in very special, complex, and often cumbersome handling systems. Early study of handling systems results in integrated reactor plans with economic fueling cycles. It is obvious that the faster the fuel loading, the more time the plant can remain on the line.

Duty-cycle considerations. Equipment must suit the duty cycle imposed on it by the reactor operating characteristics. Long periods between loadings allow portable handling systems with all other reactor considerations taking precedence over handling. The device can operate slowly and have a relatively long set-up time and can be maneuvered manually with mechanical assistance. Further, it can utilize equipment having a very limited life span. Spent fuel elements can be moved through a simple series of steps from reactor to shipping cask. The handling equipment must have a high degree of reliability during operating periods, however, the long periods between loadings afford accessibility and time for maintenance.

Cask-type machines. An example of a cask-type handling system for a reactor of these characteristics is illustrated in Fig. 2. Cask-type loading machines are especially applicable to mobile reactors for airplanes, ships, and railroad locomotives. Possible refinements in these machines are probably evident to the reader. The machine can be heavily shielded for a simple manually operated mechanism or it can be unshielded and remotely operated. A cask machine offers a way of handling for stationary reactors when other methods are disabled or as a handling device for control rods, sleeves, and other infrequently replaced reactor components.

Frequently-loaded reactors. Short periods between loadings impose a different set of requirements. Then the handling system must be perma-

nently integrated into the reactor plant. It governs building and reactor design. Loading and unloading must be quick and efficient; maneuvering must be accurate and fast. Operating features must be simple and foolproof, with the skill transferred from operator to machine. The equipment must be rugged and have long life, and yet provision must be included for maintenance. The fuel-element assembly must be carried efficiently through the series of steps from reactor core to shipping cask or process line. Examples are provided by the handling systems for pressurized-water and sodium-cooled reactors given in Figs. 3 and 4.

Fixed fuel-handling equipment must be highly reliable since failure of certain components may be very costly and time-consuming to repair. Good design, careful maintenance, thorough inspection, and extensive testing are required. Plans for remote-handling equipment should embody means for periodic inspection and repair. Attainment of reliability is intimately associated with the engineering decisions on over-all plant layout and reactor configuration. Handling equipment is subjected to severe environmental conditions. It must be able to withstand heat, radiation, and corrosive or damaging liquids (Na or H_2O). Lubrication is generally unfeasible from reactor-coolant and other aspects. Operation of equipment must be possible without vision or, at best, with limited vision.

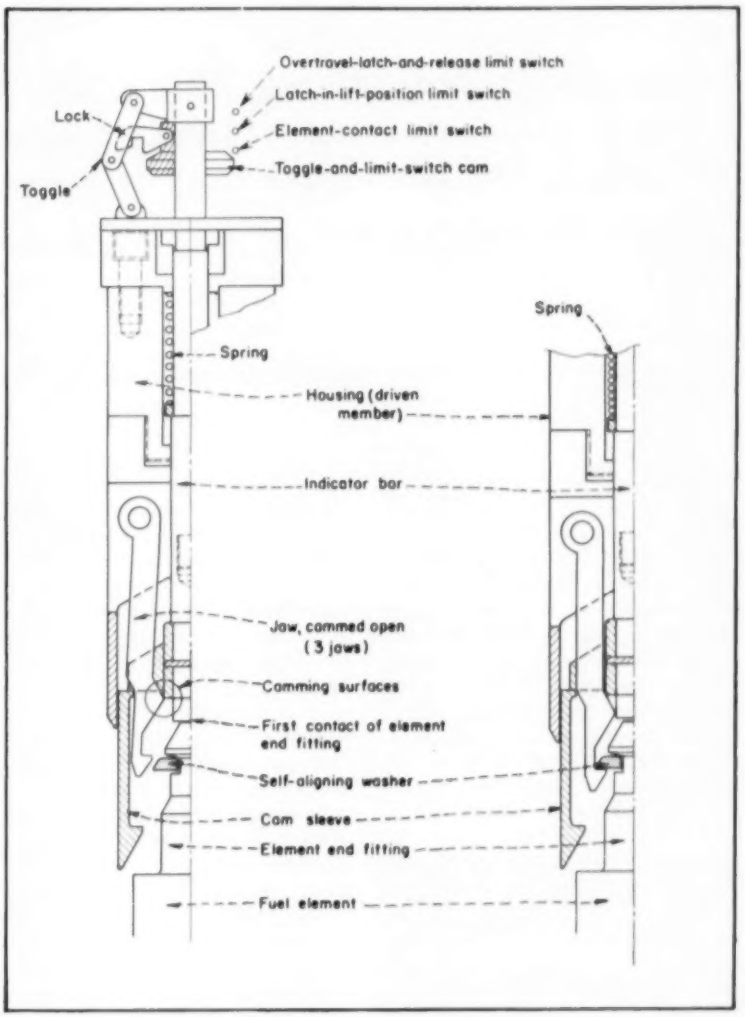
Reactor cores generally have a number of fuel elements arranged in a lattice. Consequently, handling systems must be able to move to positions from which the devices can connect to fuel elements in the core and in the fuel-entrance and fuel-discharge area. The positioning control is closely related to the geometric pattern of the core, fuel-element shape, number of elements, and geometric pattern of the reactor room. Achieving the required accuracy of positioning depends on fuel-element and handling-device design. As power reactors are high-temperature machines, the dimensions of the geometric patterns are subject to change from thermal effects. Experience has provided equipment satisfying these formidable requirements.

* * *

The information contained in this article was developed under Atomic Power Study Agreements with the U. S. Atomic Energy Commission.

5. Latch for Holding Fuel Elements

At the lower end of a fuel-element handling device is the gripper that makes connection between fuel element and handling device. The figures below show a remote-operated self-centering latch in operation. The mechanism consists of a central indicator bar within a coaxial housing. The indicator bar can move relative to the housing but to do so it must compress a spring mounted between the two



LATCHING: Here latch is being driven down through outer housing. Cone-shaped inner mouth of latch centers latch on cone-shaped upper end of stationary fuel-element assembly. Jaws are cammed open by cam sleeve that is rigidly connected to indicator bar. Spring in housing keeps cam position such that jaws are open. As housing is driven farther down it moves relative to indicator bar which is stopped by fuel-element assembly. Jaws move with housing and are cammed closed by cam sleeve

LATCHED: When jaws have closed, limit switch at upper end of latch stops drive and toggle lock locks near dead center. Then lock drops so as to lock very securely the handler and fuel element. Housing can then be elevated with indicator bar and secured element. Note that weight of fuel-element assembly tends to keep latch locked. Delatching is by a reversed procedure: unit is driven down till fuel element is stopped by a fixed surface; further travel of housing opens toggle and then jaws

How to Design Reactor Shields for Lowest Cost

Analyzing shielding effectiveness and material costs shows the starting points in low-cost reactor-shield design. Separate calculations establish optimums for the thermal and biological shields, after choosing the attenuation required of each

By JAMES A. LANE, *Oak Ridge National Laboratory,* Oak Ridge, Tennessee*

THERMAL- AND BIOLOGICAL-SHIELD THICKNESS has an important bearing on building cost and thus on power cost in nuclear power plants. A method of finding optimum shield design for minimum cost is given. The assumption is that the biological shield protects personnel only, by attenuating neutrons and γ-rays. The thermal shield prevents excessive heat generation in the biological shield, so no supplementary cooling is required.

Neutron and γ-ray fluxes at the boundary between the shields can be established. These determine the attenuation required. This, in turn, enables each structure to be optimized separately to find the optimum for the whole structure.

Biological-Shield Design

Experience has shown that water, iron and concrete appear to be the most promising materials for biological shields. Using conservative values for the thermal conductivity and thermal-stress limitations for concrete shields, the maximum tolerable heat flux on the inside surface is about 100 Btu/hr/ft^2. This gives about a 50° F temperature rise in the shield.

The radiation intensity corresponding to this heat flux is about 2×10^{11} Mev/cm^2/sec. Using 2 Mev/γ-particle—the mean γ-energy emitted by a typical chain-reacting core—γ-flux is calculated as 10^{11} γ/cm^2/sec. To reduce this to the tolerance level of 2,000 Mev/cm^2/sec (equivalent to about 4 mr/hr), requires an attenuation factor of 10^8. For these calculations neutron flux on the shield was assumed to be low enough (10^{10} n/cm^2/sec) so that the contribution of γ-rays from neutron capture can be neglected.

Radiation attenuation from distributed sources depends on source geometry and shield material. Suitable formulas are available for calculating shield thicknesses for point sources, plane sources, slab sources, and other cases (*1*). For a generalized approach, the assumption is that attenuation through $r_2 - r_1$ cm is

$$I/I_0 = B(r_1^2/r_2^2)e^{-\mu(r_2-r_1)}$$

where I_0 = incident radiation, mr/hr or γ/cm^2/sec; I = emergent radiation, mr/hr or γ/cm^2/sec; r_1 = internal radius of shield, cm; r_2 = external radius of shield, cm; B = build-up factor due to multiple scattering; and μ = gamma ray absorption coefficient, cm^{-1}.

As a first approximation, the build-up factor, B, and the geometrical factor, r_1^2/r_2^2, may be assumed to compensate for one another.

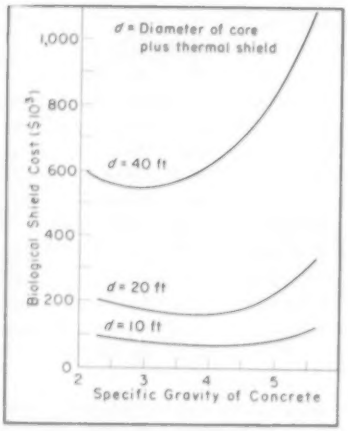


FIG. 1. Biological-shield cost is shown as function of shielding-concrete specific gravity and size of reactor core plus thermal shield. Core is cylinder with height equal to diameter. Concrete s. g. of 2.3 results with ordinary concrete, s. g. of 5.6 results with iron-aggregate concrete

Attenuation is then $e^{-\mu(r_2-r_1)}$ and for the case being considered

$$r_2 - r_1 = 8/\mu \log_{10} e$$

Concrete Shields

The densities, γ-ray absorption coefficients and thicknesses of concrete necessary for an attenuation factor of 10^8 are given in Table 1. Data for a water shield are included for comparison.

The cost of materials used in the shield can be estimated from the cost of aggregates and cement. This is given in Table 2, along with installed

* Operated by Carbide and Carbon Chemicals Co. for the U. S. Atomic Energy Commission.

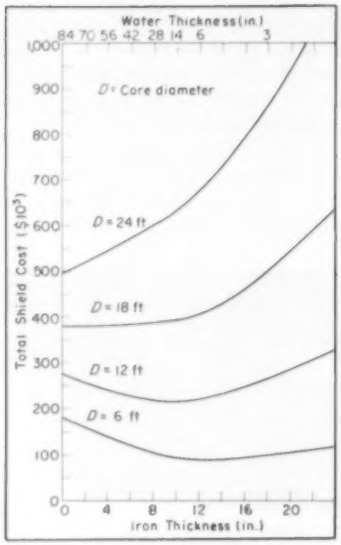


FIG. 2. Cost of entire shield is shown when using different thicknesses of iron and water in thermal shield. Needed attenuation of thermal shield can be achieved using different amounts of iron and water. Barytes concrete is assumed as material of biological shield

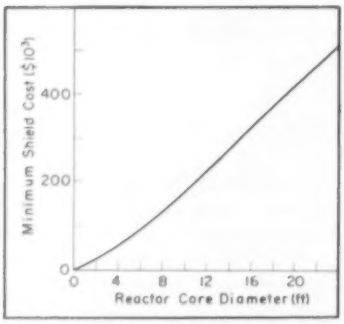


FIG. 3. Minimum cost of shielding reactor shows almost linear variation with reactor core diameter. Assumptions are that barytes concrete is material of biological shield and optimum combination of iron and water is used in thermal shield

costs for shields of different aggregates. Davis, p. 60, presents a detailed study on shielding-concrete cost, composition, and construction methods.

Biological-shield costs. Cost estimates for the biological shield are shown in Fig. 1. The reactor core was assumed to consist of a cylinder, with height equal to diameter. Calculations were based on the core being surrounded by an appropriate thermal shield, and a biological shield with thickness as given in Table 1, at unit cost shown in Table 2.

For each size core there is an optimum shield density. For reactor core diameters of interest in industrial power production (10–30 ft), this optimum density is obtainable using barytes-aggregate concrete.

Thermal-Shield Design

Designing an economical thermal shield involves heat removal and shielding problems. Lansing, p. 58, presents a detailed analysis of thermal conditions in the thermal shield. Because the thermal shield must attenuate neutrons and γ-rays, thermal shields are usually alternate layers of a heavy material like iron, lead or concrete and a light neutron-moderating material. Water is often used as the moderator, coolant, and neutron absorber.

Using other hydrogeneous materials such as high-boiling-point organic coolants may have advantages for some reactor types. In all cases the heavy material and coolant (or neutron attenuator) must be properly proportioned to design the lowest-cost shield. Optimizing the thermal shield is illustrated in the following:

Neutron and γ-ray attenuation required of the thermal shield will depend on the reactor type, the core size, the specific power and other factors. In most industrial power reactors, total neutron leakage must be held to a minimum for good neutron economy. An analysis of various designs shows that neutron flux at the thermal-shield face at reactor centerline will not exceed about 5×10^{13} n/cm²/sec, maximum; and that average flux will not exceed 2×10^{12} n/cm²/sec. The corresponding γ-ray fluxes will be this same order of magnitude.

Neutron and γ-ray fluxes on the biological shield have already been established at 10^{10} and 10^{11}, respectively. Maximum attenuation required by the thermal shield then will be 5,000 for neutrons and 1,000 for gammas. (For γ-ray attenuation, the neutron and γ-fluxes are added because each neutron absorbed yields a capture γ-ray.) Required iron and water thicknesses for these attenuations are shown in Fig. 2. The combinations of iron and water, such as 0 and 84 in., 2 and 70 in., give the desired shielding. For all shields with water thickness $\geq$12 in., γ-ray attenuation is the controlling factor in total thickness.

As iron thickness is increased, water thickness and thus total thermal-shield thickness decreases. This decreases the biological-shield size and cost. At some point the amount of water becomes insufficient for neutron attenuation, and the thermal-shield thickness starts to increase. In Fig. 2 thermal- plus biological-shield cost is given for various core diameters, assuming a cylindrical core, with diameter equal to height. To calculate costs

TABLE 1—Shielding Thickness

Shield material	*Specific gravity*	*Absorption* (cm^{-1})*	*Needed thickness (ft)*	*Aggregate (tons/yd³)*
Water	1.0	0.029	21	0
Standard concrete	2.3	0.067	9.1	1.65
Barytes concrete	3.5	0.100	6.0	2.66
Iron-aggregate concrete	5.6	0.162	3.8	4.45

* These absorption coefficients are for a gamma energy of 2–3 Mev.

TABLE 2—Biological-Shield Unit Costs

Concrete type	*Cost*		
	Aggregate ($/ton)	*Materials ($/yd³)*	*Installed cost* ($/yd³)*
Standard	18	75	150
Barytes	36	140	250
Iron-aggregate	125	600	800

* These costs include $5/yd³ for portland cement and $40/yd³ for forms and reinforcing materials. Installed costs estimated on this basis are costs for high-construction-cost areas, rather than average costs. At Oak Ridge National Laboratory installed cost of ordinary-concrete reactor shields is $120/yd³ (including overhead), and the corresponding cost for barytes concrete is $175/yd³. Davis, p. 60, presents installed costs at Hanford Atomic Products Operation for several concrete types.

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the biological shield was assumed to be barytes-aggregate concrete. Steel cost was taken as $0.30/lb, installed. The results indicate that steel thickness should be decreased as reactor-core size increases. Minimum total cost for the biological and thermal shield, for core sizes up to 24-ft diameter, are plotted in Fig. 3.

The cylinder shape used in these calculations is the optimum cylinder for reducing shielding costs, as it has the lowest surface area/volume ratio. Lower shielding costs would result from placing the reactor in underground tanks, as the biological shield could be eliminated. A thermal shield would still be needed to prevent overheating in the tank walls.

BIBLIOGRAPHY

1. T. Rockwell, A. Kitzes, ORNL-701 (1951)

Determining the Geometry of Thermal Shields

Gross amounts of iron and water in thermal shield can be set by shielding requirements, but their distribution must be set by calculations on thermal stresses and heat transfer. Here's how to carry out this type of analysis

By NEAL F. LANSING

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MATERIAL CONFIGURATION IN THE THERMAL SHIELD must be chosen so that flow and heat-transfer characteristics are satisfactory. Material geometry must insure that thermal stresses will not exceed permissible values. After selecting the gross quantities of materials needed to achieve the required thermal-shield attenuation, the details of material distribution must be established. To illustrate the procedure, thermal-shield design for a 12-ft-diameter reactor core will be described.

The core is a cylinder with diameter and height equal. Lane, p. 56, has shown that for this size core, the lowest shielding cost results from using 10 in. of iron and 14 in. of water in the thermal shield. The water and iron are assumed to be discrete layers. Such laminated thermal shields are more conventional, but it is possible that a nearly homogeneous mixture of iron and water, such as iron shot through which water circulates, would be preferable.

First Water Layer

The first layer of water should be 8 in. thick (*1*). This layer reduces thermal-neutron flux on the iron. Two advantages result from this attenuation: (*a*) reducing energy release per neutron capture from 7 Mev in iron (*2*) to 2.2 Mev in water, and (*b*) releasing almost all the capture-γ-ray energy inside the thermal shield instead of distributing this energy source throughout the shield volume.

A further advantage of this initial water layer is that it reduces γ-ray intensity by one-third. Thus the water absorbs a significant amount of energy so far as thermal effects are concerned, although the effect is almost negligible so far as over-all shield attenuation is concerned.

Maximum γ-ray flux leaving the core has been estimated as 2×10^{14} Mev/cm²/sec (p. 57) which includes the γ-rays from neutron capture. Assuming the average energy of the γ-rays is 2 Mev, the water absorption coefficient is 0.05 cm^{-1}. The 8-in. water layer will reduce the γ-ray energy to 7×10^{13} Mev/cm²/sec. In engineering units, this is an energy flux of 35,000 Btu/hr/ft² incident on the first iron layer. An expression for thermal stress caused by heat generation in the shield will next be derived.

Thermal Stress in Shield

Heat generation in thin layers of material surrounding large sources of nuclear radiation is $Q = B\,Q_0 e^{-\mu x}$. "Symbols, Units and Physical Constants," p. 59, explains the units used.

Over a small number of relaxation lengths, the build-up factor, B, can be approximated by (*3*) $B = B_0 e^{cx}$. The heat generation function then becomes $Q = Q_0 B_0 e^{-\mu x}$, where $\mu = \mu_l - c$ (effective linear-absorption coefficient).

In any irradiated shell whose thickness, L, is small compared to its radius, the temperature distribution is $k(d^2t/dx^2) = -Q_0 B_0 e^{-\mu x}$. Letting t_1 be the surface temperature on both faces gives the following expression that

* Operated by Carbide and Carbon Chemicals Co. for the U. S. Atomic Energy Commission.

Symbols, Units and Physical Constants

Values given are for carbon steel

B_0 = constant = 1.5

c = constant = 0.11 cm^{-1}

E = elastic modulus, 30×10^6 psi

I_0 = incident radiation intensity, Mev/cm^2/sec

k = thermal conductivity, 26 Btu/hr/ft/°F

q/A = heat rate, Btu/hr

Q = heat generation in shield, Btu/hr/ft^3

Q_0 = heat generation at shield surface = $I_0\mu_c$ = 1.87×10^3 Btu/hr/ft^3

r = radial coordinate, cm

t = temperature, °F

t_a = average shield temp., °F

t_f = average coolant temp., °F

x = shell thickness measured from irradiated surface, cm

α = thermal-expansion coefficient = 7×10^{-6}/°F

μ = effective linear absorption coefficient = 0.22 cm^{-1}

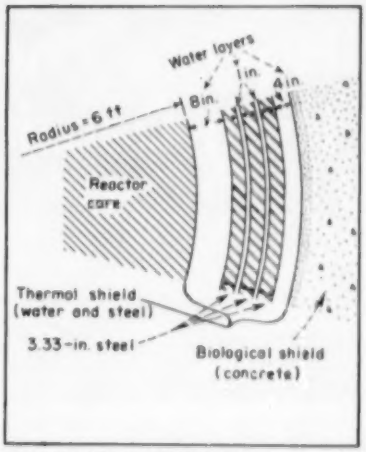
μ_c = energy absorption coefficient = 0.175 cm^{-1}

μ_t = average linear absorption coefficient = 0.33 cm^{-1}

ν = Poisson's ratio = 0.3

σ_z^0 = permissible axial stress, 30,000 psi

Ψ = stress function



THERMAL-SHIELD DESIGN splits iron needed into three shells; and water into four

closely approximates the results of more refined analyses: $\mu^2 k(t - t_1)/B_0 Q_0 = 1 - e^{-\mu x} - (1 - e^{-\mu L})x/L$. This temperature distribution is then used to evaluate the thermal stress.

Postulating that pressures are balanced on either side of the shield, conventional stress formulas (4) can be taken directly. Experience indicates that the axial-stress component usually predominates. Axial thermal stress in a hollow cylinder of inner and outer radii a and b, respectively, is

$$\sigma_z = \frac{E\alpha}{1-\nu}\left(\frac{2}{b^2-a^2}\int_a^b (t-t_1)r\,dr - (t-t_1)\right) \quad (1)$$

Introducing the temperature distribution given leads to an exact solution that can be simplified for thin shells

$$\frac{\sigma_z(1-\nu)k\mu^2}{\alpha E Q_0 B_0} = \xi\left(1+\frac{\mu L}{6}\right)\epsilon - \frac{\xi - e^{-\mu L}}{\mu a}(1-\epsilon) - \left(1+\frac{\mu L}{2}\right)\xi + e^{-\mu x} + \xi\mu x \quad (2)$$

where ξ represents $(1 - e^{\mu L})/\mu L$ and ϵ is $L/2a$. As maximum stress occurs at either surface the expression used for design is

$$\Psi \equiv \frac{\sigma_z^0(1-\nu)k\mu^2}{\alpha E Q_0 B_0} \leq 1 + \xi\left(1+\frac{\mu L}{6}\right)\epsilon - \frac{(\xi - e^{-\mu L})}{\mu a}(1-\epsilon) - \left(1+\frac{\mu L}{2}\right) \quad (3)$$

This relationship gives the stress function, Ψ, in terms of the number of relaxation thicknesses, μL, of the shield. It is an expression of the familiar form $\sigma_z^0 = \alpha E(t_a - t_1)/(1 - \nu)$ in which terms in ϵ^2 have been neglected.

By way of comparison, for an irradiated flat plate with similar boundary conditions $t_a - t_1 = Q_0(1 - \xi - \xi\mu L/2)/k\mu^2$.

Using the heat flux previously calculated and Eq. 3, the maximum allowable thickness of the first iron layer in the shield, based on thermal stress considerations, is found. Physical constants are above. From the shield inner dimension $\mu a = 40$. Using the maximum steel thickness required (10 in.), $\mu L = 5.7$, for which the right-hand side of Eq. 3 = 0.28. For carbon steel $\Psi = 0.42$. This means that maximum stress in a single slab of the required thickness will be less than permissible stress. Thermal-shield design for this case will be controlled by the heat load rather than thermal stress. How the materials are distributed is shown next.

Choosing Layer Thickness

Layer thickness usually depends on an economic optimization. The variation in energy-absorption rate in slabs one or two relaxation-lengths thick is such that the required heat transfer from one surface is $q/A = I_0(1 - e^{-\mu L})/2$. Heat transferred to the coolant will be $q/A = h(t_1 - t_f)$. Both the heat transfer coefficient, h, and $(t_1 - t_f)$ can be varied over quite wide ranges.

The heat transfer coefficient for ordinary fluids such as water and air is most sensitive to the flow velocity. Permissible temperature difference depends on the system pressure and other conditions. Because many of these conditions will be established by considerations other than cooling the shield, it is not possible to set forth a systematic optimization procedure for heat removal.

In this case the relatively low heat flux makes it convenient to absorb most of the energy in a single layer. Say that 30,000 Btu/hr/ft^2 are removed by a single steel layer. This would require the first layer to be 3.6 in. thick. Heat transfer rates of 15,000 Btu/hr/ft^2 readily result from temperature differences of 50–100° F and water flow velocities of 1–2 ft/sec for passages on the order of 1 in. wide. For more economical fabrication, equipartition of the needed steel into three layers, each 3.33 in. thick, would probably be recommended.

The additional 6 in. of water needed for the shield can be used as shown in the figure. The final 4-in. water layer thermalizes and absorbs neutrons that have been degraded by the steel.

The analysis just described applies only to continuous shields. Openings in the thermal shield, such as for beam holes and instrument thimbles, will allow radiation to stream through. This often creates local "hot spots" in the biological shield for which provision must be made individually.

BIBLIOGRAPHY

1. Oak Ridge National Laboratory physics division, shielding section (unpublished)
2. P. S. Middelman, R. A. Liedtke, Nucleonics **13**, No. 5, 50 (1955)
3. J. Moteff, APEX-176 (1954)
4. S. Timoshenko, J. Goodier, "Theory of Elasticity" (McGraw-Hill Book Co., Inc., New York, 1951)

How to Choose and Place Mixes for High-Density Concrete Reactor Shields

Selecting the best concrete for shielding means choosing from among densities of 150–410 lb/ft³, at material costs from $0.50–25.40/ft³. This article tells how high-density concrete can be designed and placed at lowest cost. Properties of available heavy aggregates and usable mixes are given, plus construction techniques

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General Electric Co.
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CONCRETE IS AN EXCELLENT MATERIAL for radiation shielding. It is economical, stable and versatile. In addition, it may be used structurally.

Ordinary concrete made with sand and gravel weighs about 150 lb/ft³ and costs $50–100/yd³, installed. Shield thickness can be reduced by using denser concrete. This often results in over-all savings in reactor and building costs. Concrete made with natural heavy aggregates such as magnetite will weigh up to 245 lb/ft³, while densities to 425 lb/ft³ can be obtained using steel punchings and shot. High density concrete costs $100–1,300/ft³, in place, depending on aggregate type and formwork used.

Cost savings by proper design can be considerable. Using high-density concrete saved $7,000,000 on one reactor project. On another job $440,000 was saved by using magnetite rather than steel aggregate in a less critical area where maximum density was not required.

Concrete-shield thickness usually can be reduced in the same proportions as the density is increased. What density and composition is the best depends on many factors.

Factors to Consider

The best shield design provides adequate protection at reasonable cost. The following design factors must each be considered for each shield:

Shielding effectiveness. Complete data on shielding properties of the mixes discussed are unavailable. Lane, p. 56, presents absorption coefficients for some concrete types. More detailed data are available (*1–6*). When shielding neutrons, the concrete must contain hydrogen (water), other light elements, or special admixtures (see p. 63).

Shield density and composition. Where space is limited, expensive high-density aggregates may reduce total cost. But to reduce total cost of a large shield, cheap sound aggregates are imperative. Shield density and composition is influenced by: (*a*) type and intensity of radiation, (*b*) limitations on shield thickness, (*c*) complexity of forms or shielding structure, (*d*) number and location of embedded items, (*e*) construction methods, (*f*) temperature and operating conditions, (*g*) external and dead loads, (*h*) available aggregates, and (*i*) economy.

Placement method. To get concrete with the desired composition and uniformity, reasonable care must be used while handling aggregates and placing concrete. The correct placement method reduces costs and insures uniformity.

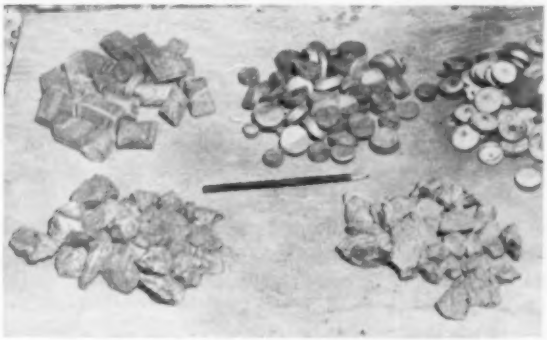
Adequate structural strength. High-density concrete with adequate structural strength and stability can be obtained using sound aggregates. Construction experience demonstrates that compressive strengths of 2,000–6,000 psi can be obtained at 28 days in concrete made with portland cement and aggregates of iron, magnetite, limonite, or barite. Some compromise in strength may be necessary for economy, or for high water content and density. The concrete types described are structurally sound and capable of adequate behavior if operating temperatures are not excessively high.

Stability under operating conditions. Recent experience indicates that reasonable amounts of gamma and neutron exposure do not deteriorate sound concrete appreciably. Some strength loss has been noted during tensile or flexural tests with heated specimens; however, this loss is caused mainly by water loss during heating. Proper allowances can be made for temperature effects when selecting materials, working stresses, and shield thicknesses. Thus, the art of concrete design and construction can be extended confidently to high-density concrete by allowing for the special properties of heavy aggregates.

Designing Dense Concrete

Extensive experience with ordinary concrete has resulted in recommended procedures and basic relationships (*7*) that can be used as guides in high-density concrete design. For a gamma shield, emphasis should be on getting high-density, optimum-graded aggre-

How High-Density Concrete is Placed, Using the Prepacked Method:



1 STEEL OR NATURAL ORES ARE TYPICAL HEAVY AGGREGATES. Sheared steel bars and punchings (top) and coarse magnetite and limonite ores are typical heavy aggregates for shielding concrete. Steel pieces should be free of dirt, oil or coatings that reduce cement bonding; natural aggregate should be cheap, dense, clean, and free of deleterious material

2 NATURAL ORES ARE REDUCED IN SIZE BY CRUSHING EQUIPMENT. Limonite ore is crushed for concrete use; first in jaw crusher (background), then in gyratory crusher at right. Vibrating screens sort the ore. Grout sand is ground in ball mill at left. After crushing, aggregates are weighed, and then blended in concrete mixer. Fines are removed by washing on $\frac{3}{8}$-in. vibrating screen

3 (LEFT) NEXT, AGGREGATES ARE PLACED AND COMPACTED IN FORMS. By carefully placing and compacting aggregate in steel forms for side shield of reactor, breakage and size segregation are minimized. Aggregate should not be stockpiled, but should be placed in batches of 0.5 to 1-yd^3

4 (RIGHT) DIFFERENT AGGREGATES ARE USED AROUND EMBEDDED ITEMS. Magnetite-limonite aggregate is used in less critical areas at the left. Steel-limonite aggregate is placed around beams and embedded items

5 GROUT IS PUMPED UPWARD, FILLING VOIDS IN AGGREGATE MASS. Grout is pumped to lowest part of shield and forced up with pressure of 2 ft of water. Two trailer mixers and four duplex pumps supply grout at 6 yd^3/hr

6 STEEL SKIN PLATE COVERS FINISHED CONCRETE SHIELD. Top surface of shield is finished by conventionally placing 10 in. of high-density concrete. Shield is then covered with steel skin plate

gates and determining a mix of desired density and minimum cost.

Proportions for shielding concrete should produce concrete with the required properties as cheaply as possible. Because portland-cement cost is a much smaller fraction of material cost for high-density concrete than for ordinary concrete, there is little incentive to reduce the cement content except when maximum density is most important. In heavy-aggregate concrete, cement content may be higher to improve workability or increase fixed-water content.

Resistance to high temperatures and thermal cycles is more important than resistance to wetting and freezing cycles.

Heavy-aggregate size distribution is important when using aggregate 3–5 in. maximum. Material costs can be reduced by using heavy aggregates as they come from the crusher if maximum size is 1–1.5 in., in which case distribution is less critical.

Choosing Heavy Aggregate

What heavy aggregate is used greatly affects the concrete shield's properties and cost. Of about 60 minerals with specific gravity >3.5, about 10 mineral groups are commercially available. Of these, barite, magnetite, limonite, and goethite are most suitable. Heavy ores like hematite, taconite, arsenopyrite, chromite, psilomelane, and galena are of interest, but have not been used widely. Heavy slags or smelter by-products like ferrophosphorus may be used. Although quite expensive, iron aggregates such as steel shot, punchings and sheared bar stock may be used.

"Cost, Composition, and Properties of High-Density Concretes," p. 64, presents tabular data for nine typical aggregates and 17 types of concrete. Total installed cost is given for five concretes. What placement method is used greatly affects the concrete quality.

Choosing Placement Method

Special equipment is not required for handling heavy aggregates or for placing high-density concrete. Allowance should be made for high-density. Ordinarily, batch volume can be reduced so mixers and trucks will not be overloaded.

Reasonable means should be taken to minimize aggregate breakage and size segregation. As long as aggregates have about the same density, segregation can be controlled satisfactorily by using standard methods designed to minimize it. But it is almost impossible to prevent steel punchings from segregating. For this reason, the conventional method is not recommended for placing concrete containing punchings.

Conventional method. The conventional method includes procedures in which the aggregates, cement, and water are mixed in a conventional mixer and then poured into the forms wet. Except for concrete containing aggregates with large specific-gravity differences, the conventional method usually produces shielding concrete of excellent quality. Standard procedures (*8*) should be followed. Special care should be taken to prevent equipment overloading and aggregate segregation. Vibration during this method and the pumping method must be used with discretion.

Pumping method. Pumping the wet concrete from mixer to forms in a specially constructed pipe line is an extension of the conventional placement method. Special mixing and pumping equipment is available for ordinary concrete. By allowing for the increased density this equipment may be used for concrete made with dense natural aggregates.

Usually, the maximum density obtainable is considerably less than for concrete placed by the other methods. Pumping concrete containing large pieces of steel aggregate is not recommended. However, heavy grouts or mortars containing steel shot, pulverized iron or fine ferrophosphorus can be pumped satisfactorily.

Puddling method. To minimize some of the handling difficulties of concrete containing coarse aggregates of steel punchings or scrap iron, the "puddling" method may be used. Several inches of mortar are placed in the form and covered with a uniform layer of coarse-metallic aggregate. The coarse aggregate is then puddled into place by rodding or internal vibration. Close control of mortar consistency and composition is required to obtain uniform density in successive layers.

This method is limited to open forms relatively free of embedded items and windows, because it is extremely difficult to move coarse aggregate once the aggregate is stuck in the mortar.

Prepacked method. In this method, the coarse aggregate is prepacked in the forms and the void space filled with a special grout (intrusion mortar). The method has these advantages (*9*): (*a*) segregation of coarse metallic aggregate can be minimized, (*b*) concrete of uniform density and composition can be placed easily in restrictive areas and around embedded items, (*c*) for similar materials, greater density and homogeneity can be obtained more consistently than by other methods. Coarse aggregate blending for the prepacked method can be done accurately and efficiently with commercial equipment adapted for the job. Specified amounts of heavy aggregates can be batched in a weigh batcher and then blended in a concrete mixer or on a mixing belt. The illustrations on page 61 show the steps in placing concrete by the prepacked method.

Summary. Ordinarily, conventional methods will be cheaper; therefore, when natural heavy aggregates are used and the forms are relatively free of embedded items, there is little incentive to use special methods. The prepacked method gives more positive assurance than other methods that the heavy-aggregate distribution is uniform and that no large voids exist. If the concrete contains mixed aggregates, or is placed in complex forms and around closely spaced embedded items, the prepacked method should be considered seriously.

Shield Construction

Reasonable means should be taken to buy sound, high-density aggregates. Realistic specifications must be written. Transportation and processing costs must be included in total material cost. In one case, freight charges were three times the cost of ore at the mine.

Processing the aggregate. The most positive procedure for obtaining heavy aggregates is to purchase processed material. Processed magnetite and barite can usually be obtained. Some mines do not have crushing facilities. In such cases it may be necessary, or desirable, to purchase mine-run ore and process it at the job site. Quality control is very important and is easier at the job than elsewhere.

Tests should be made to determine whether ore from a particular source will produce sound aggregate. Deleterious materials should be determined; barite may contain too much opal and

How to Increase Neutron-Shielding Effectiveness

Neutron-shielding effectiveness can be improved by (a) using a high content of iron or heavy elements such as barium, (b) increasing the water content, (c) adding boron compounds. Optimum composition for a fixed-density concrete shield is uncertain. Boron content is limited to about 1% because greater amounts have a degenerative effect on setting time and physical properties (6). Optimum water content is also unknown; however, it appears that below 4% neutron-shield efficacy is impaired.

Boron-Loaded Concrete

Oak Ridge National Laboratory has developed high-density concretes containing boron (6). They weigh about 200 lb/ft³ and contain 1% B and 8% water when wet. About 400 lb of colemanite or 670 lb of boron frits/yd³ of barite concrete produce this concrete. Colemanite ($2CaO{\cdot}3B_2O_3{\cdot}5H_2O$) powder is more soluble than boron frits and affects concrete hardening more adversely. To counteract the setting delay high-alumina cement may be used with portland cement.

Concrete made with frits (formed by fritting borax with silica) will cost more, contain less water for the same boron content, but be easier to formulate and cure.

ORNL reports that satisfactory concrete with colemanite or frits can be formulated and cured. Material cost will be >$6/ft³, or two-to-three-times material cost for boron-less concrete with similar density. At this price, it is difficult to justify using boron except for special applications.

Increasing Water Retention

All the water added to a concrete mix does not remain; part of it is fixed—chemically bound by the hardened cement paste—and part is evaporable. In general, the higher the initial water/cement ratio, the damper the curing conditions, the longer the curing period, and the lower the operating temperatures—the higher will be the fixed-water content of a concrete shield. Other factors are: type of sand and cement; shield dimensions and geometry; and relative humidity. For average curing conditions, fixed water contained by hardened mortar at 100° C will be about 15% of the portland cement by weight. Under more favorable design and curing conditions, 20 to 23% may be retained at 100° C (10).

Special cements have been used experimentally to retain greater amounts of fixed water than does portland cement (6, 11, 12). Satisfactory concrete has been made using magnesium-oxychloride (MO) cement, barite and ferrophosphorus (13). Iron aggregates can not be used successfully in concrete made with MO cement because they rust and destroy the bond between paste and aggregate. Most concrete shields built have used portland cement. The portland cement industry could aid concrete-shield development by supplying a non-air-entraining cement, of uniform properties, that would retain more water than do present portland cements.

Special aggregates may be used to increase water content. Limonite, with about 10% water of crystallization, is an excellent source of fixed water as long as the temperature is not over about 200° C. Haydite has been used to retain large amounts of evaporable water. The removal rate of evaporable water from a thick concrete wall is usually relatively low, and can be reduced by applying special membranes or steel plates to the surfaces. To assure enough water in a shield, reasonable means should be taken to provide adequate curing conditions and to limit maximum exposure temperature. To a certain extent, concrete surfaces exposed to high temperatures are self-sealing in that the dehydrated concrete presents an increased barrier to water diffusion. Depending on the temperature distribution through a concrete shield and its age, water content will be substantially above the minimum values given on p. 64. For structural reasons temperature differential through a concrete shield should be limited to 20–30° C. Thermal shields, insulation blankets, and external cooling may be required.

A thermal shield usually consists of an iron inner wall, between the reactor and the shielding wall. It absorbs most of the energy from radiation leakage and protects the concrete shield.

Hard gammas created in iron thermal shields during the capture of thermal neutrons, must be attenuated in the concrete. As a means of eliminating secondary gammas, thin "boral" or "boroxal" sheets containing aluminum and boron have been suggested (14).

In any case, heat generated in a thermal shield must be removed by external means. This may be a major factor in deciding whether to use these boron sheets. Heat removal and thermal-shield design is of special importance in over-all reactor-shield design. These factors must be considered to evaluate the thermal conditions that the concrete will experience. Lansing, p. 58, presents an example of thermal shield design, including an analysis of thermal stresses.

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chalcedony, while limonite may contain too much fine clay or poor-strength weathered ore.

Magnetite and goethite ores crush similarly to basalt. When crushing coarse ore to 1.5-in. size, about 30% pass the ½-in. screen. A larger fraction of limonite will crush down to fines, depending on the ore. Barite is softer than magnetite or goethite. Breakage during handling of heavy aggregates may be high compared to breakage of the crushed rock used in ordinary concrete. Losses may be as high as 20–25%. Cost can be reduced by using as much of the material coming from the crusher as possible. Crusher fines passing the ¼-in.-screen, if reasonably well graded, can be used as fine aggregate even though as much as 10–20% passes the No. 100 screen.

Further grinding in a rod or ball mill is usually required to produce grout sand for the prepacked method. Coarse aggregates used in the prepacked method should be larger than ¾ in. They should be washed before being placed in the forms, to remove objectionable amounts of rock dust and fines. Processed aggregates should be stored on planking or concrete slabs to prevent contamination. Bagging is expensive but is usually justified for storing, handling, and batching grout sand.

Usable types of forms. Forms may be removable, made of plywood or metal; or they may be permanent and more elaborate. For walls that have no close tolerances and do not contain

1. Some of the Best Aggregates Obtainable . . .

Heavy aggregate	Source	Composition	Specific gravity* Coarse pieces	Specific gravity* Fine sand	Per cent by weight Iron	Per cent by weight Fixed water	Dollars/ton F.O.B. source	Dollars/ton Processed at job†
Limonite-goethite‡	Mich.	$2Fe_2O_3$–$3H_2O$	3.75	3.80	58	9	7	25–40
	Utah	Fe_2O_3–H_2O	3.45	3.70	55	11	11–20	40–*50*
Magnetite,	Nev.	Fe_3O_4, etc.	4.62	4.68	64	1	9	20–*30*
Magnetite	Mont.	Hydrous iron§	4.30	4.34	60	2–5	7	18
Barite	Tenn.	>92% $BaSO_4$	4.20	4.24	1–10	0	18	22–30
Barite	Nev.	>90% $BaSO_4$	4.28	4.31	<1	0	19	30–*40*
Ferrophos-phorous	Tenn., Mo.	Fe_2P, Fe_2P,FeP	6.30	6.28	70	0	80	90
Steel Aggregate	Punchings, sheared bars		7.78		99	0	120	130
Steel Shot	Chilled	SAE standard		7.50	98	0	120	130

* Material water saturated, with its surface dry.
† Processing charges include grinding and other operations to make the ore suitable for use in concrete. Freight charge of $10/ton is included. Cost of grout sand is in italics.
‡ This ore occurs as a mixture of the two minerals.
§ This ore is primarily magnetite, with some hematite (Fe_2O_3) and limonite.

2. And These Grouts, . . .

Type*	Grout sand	Sand/cement ratio weight	Sand/cement ratio volume	Water/cement weight ratio	Wet weight (lb/ft³)
S-270	#110 steel shot	3.75	1.58	0.35	270
S-250	#110 steel shot	3.30	1.39	0.35	250
M-170	Magnetite–	2.13	1.04	0.55	170
B-155	Barite–	1.49	1.10	0.54	155
L-146	Limonite–	1.28	1.09	0.55	146

* Grout sands processed from heavy ores should have a fineness modulus of 1.0–1.5; the heavier the sand the finer it must be to stay in suspension. Sands having 20–40% finer than No. 200 screen may be used if tensile strength at high temperature is not important.

Each of the above grouts are pumpable; however, the metallic ones should not be pumped into large masses of aggregates. Grout *S-250* may be pumped more easily than grout *S-270*.

3. Make High-Density Concretes for Shielding, with . . .

Concrete type	Weight (lb/ft³)	Material cost ($/ft³)	Compressive strength (psi at ( ) months)	Cement (lb/ft³)	Heavy aggregate Fine (lb/ft³); Coarse (lb/ft³)*	Admixture†	Mix water (lb/ft³)	Water content‡ (lb/ft³) Min.	Water content‡ (lb/ft³) Max.	Grout type	Placement
A	410	25.40	3,000 (3)	16.8	#110 shot 63; Punchings 324	I.A.	5.9	2.5	5.9	S-270	Puddled
B	346	18.40	3,000 (3)	20.6	Magnetite 44; Punchings 270	I.A.	11.3	3.5	11.8	M-170	Prepacked
C	300	15.40	4,700 (3)	M. O.§	Ferrophosphorous 107; 161			~9.5	15.0		Conv.
D	300	12.05	3,870 (4)	24.1	Ferrophos. 92; 171		12.7	3.6	12.7		Conv.
E	300	11.90	5,000 (3)	19.8	Magn. 42; Magn. + Punch. 67 + 160	I.A.	10.9	4.1	12.0	M-170	Pre.
F	263	11.20	6,000 (3)	22.2	Limonite¶ 28; Lim. + Pun. 60 + 140	I.A.	12.2	13.0	21.9	L-146	Pre.
G	262	11.30	7,000 (3)	34.0	Lim. 65; Shot #330 + 1320 49 + 100	Plast.	13.5	12.3	20.9	Mortar	Conv.
H	262	7.75	5,350 (4)	23.7	Ferro. + Barite 70 + 35; 70 + 50		12.8	3.6	12.8		Conv.
I	262	5.75	4,800 (3)	19.8	Magn. 42; Magn. + Pun. 122 + 67	I.A.	10.9	4.7	12.6	M-170	Pre.
J	244	2.55	5,000 (3)	17.5	Magnetite 37; 180	I.A.	9.7	4.8	11.9	M-170	Pre.
K	232	2.20	6,500 (3)	24.3	Magnetite 86; 110		11.5	5.7	13.5		Conv.
L	227	3.30	3,500 (3)	19.3	Barite 29; 168	I.A.	10.5	2.9	10.5	B-155	Pre.
M	222	3.05	6,000 (3)	19.3	Barite 86; 105	I.A.	11.6	2.9	11.6		Conv.
N	219	2.10	6,500 (3)	24.9	Hydrous iron ore 82; 100	Plast.	12.0	9.2	17.5		Conv.
O	215	2.75	5,000 (3)	22.7	Lim. 29; Lim. + Magn. 28 + 122	I.A.	12.5	10.9	20.0	L-146	Pre.
P	185	3.10	5,800 (1)	31.3	Limonite 62; 76	Plast.	15.4	17.1	27.8		Conv.
Q	154	0.50	8,800 (1)	31.3	Local sand 50; 61	Plast.	11.5	4.7	11.5		Conv.

* Where only one material is given, it is used for both fine and coarse aggregate.
† Intrusion aid, 1.5% by weight of the portland cement, is added where shown. I.A. (Intrusion Aid) is a special grout admixture designed and used by Prepakt Concrete Co., Cleveland, Ohio. Plast. (Plastiment) is a concrete densifier manufactured by Sika Chemical Corp., Passaic, N. J.
‡ Maximum water content is water weight when concrete is wet. Minimum water content is amount left after drying to constant weight at 85° C. Difference between the maximum water content and the amount of mix water added is the water of crystallization held by the aggregate. The difference between the minimum water content and the water of crystallization is the water retained by the hardened cement paste.
§ This concrete is made using magnesium-oxychloride cement, made of 12.2 lb/ft³ of MgO powder, and 19.8 lb of MgCl solution.
¶ Utah limonite is used except for mix *P* which uses Michigan limonite.

4. Adequate Physical Properties for Structural Uses, at . . .

*Concrete**	*lb/ft³*	*Bags/yd³*	*Compressive strength (psi)†*	*Rupture modulus† (psi)*	*Elast. modulus† (× 10⁻⁶)*	*Ult. bond strength† (psi)*	*Shrinkage (%)*	*Expansion (in./in./° F)*	*Specific heat (Btu/lb/° F)*	*Conductivity (Btu/hr/ft/° F)*	*Diffusivity (ft²/hr)*
Conv. (*15*)	153	~5.0	4,960	630	4.6		0.041	5.5	0.23	1.50	0.042
Q (*16*)	154	9.0	8,870	1,005	5.9	900	0.012				
P (*16*)	185	9.0	5,865	700	4.4	970	0.021				
O (*17*)	210	6.55	4,640	516	5.0	1,396	0.023	5.6	0.20	1.20	0.030
M (*15*)	226	5.1	6,130	445	4.3		0.029	10	0.157	0.884	0.025
L (*15*)	230	5.0	3,340	630	3.7		0.029	10	0.146	0.867	0.026
K' (*17*)	224	7.0	5,780	684	4.3	1,423	0.018	5.7	0.21	1.68	0.034
F (*17*)	273	6.55	3,180	406	5.4	1,266	0.013	5.9	0.18	2.75	0.056

* Concrete composition is similar to that given in table of concretes, except for *K'* that has 46-lb limonite and 0.6-lb fixed water/ft³. Conv. is Grand Coulee concrete. Placement method is given in table, p. 64. The limonite used was from Michigan; the barite was from Nevada; specific gravity of magnetite was 4.4.

† Strength values are for moist cured specimens, 28-days old.

5. Varying Total Cost.

Concrete	*Type*	*Cost ($/yd³) Forms*	*Cost ($/yd³) Concrete*	*Total cost/lb (cents)*
Ordinary structural		45	25	1.7
Ordinary	Q	60	40	2.4
High density	*K* or *N*	100	120	3.7
High density	*O*	300	250	9.5
High density	*F*	600	500	15.5

INTERPRETATION—Material cost on p. 64 includes costs for raw material, transportation, processing and handling. Cost can be adjusted for local prices using the mix data. Costs increase with density and water content. For neutron shielding about 4% water content is a minimum. Limonite, combined with barite, magnetite, or steel aggregate, raises fixed water content to about 5%. By varying the amounts of magnetite and limonite, density can be varied from 175–250 lb/ft³, with corresponding fixed water content from 20–30 lb.

Natural-aggregate concretes cost 1–1.5¢/lb for materials. Using iron aggregate, densities from 240–425 can be obtained at 2–6¢/lb. This concrete can be justified only where space is at a premium.

The greatest potential cost savings are in simplifying formwork, reducing labor and using natural heavy aggregates rather than steel. Estimated costs at left show that usually form cost is over half the total cost. In the first three cases, temporary plywood forms were used, while permanent steel forms were used in the others.

On one job using elaborate steel forms cost breakdown was: 16%-form fabrication, 20%-materials other than aggregate, 30%-labor at the site, 12%-equipment, 15%-steel aggregate, 7%-limonite and magnetite aggregate. Limonite and magnetite are over 50% of the concrete's volume.

many embedded items, formwork can be relatively simple and cheap. However, formwork must be more rigid and stronger than for ordinary concrete. Curing methods and conditions should be chosen to assure concrete with the desired strength and water content.

Maintainable alignment tolerances. For some shields, close tolerances must be maintained in tube and process-equipment alignment. Plywood forms with oversize holes can be aligned in the field to $\frac{1}{32}$-in. tolerance using a transit. Portable steel jigs can be used in conjunction with plywood forms.

By using permanent steel forms with drilled holes, numerous tubes can be located to within $\frac{1}{64}$ in. Permanent steel forms may be required to support structural loads during and after construction, provide additional shielding, protect the concrete, act as a reactor-gas barrier, and provide means for attaching equipment to the shield.

It is true that close tolerances are necessary for some types of shield construction; however, their need should be questioned carefully and justified for each component. Certainly there is no excuse for specifying tolerances that can not be obtained in the field or that can not be justified on the basis of requirements. Likewise, the use of permanent steel forms should be questioned as they may double shielding cost.

Quality control. Adequate control measures are required during all phases of construction. Aggregates, cement, and water used in mixing prepack grout or conventional concrete should be weighed as accurately as possible. Standard specifications and procedures should be followed. In general, the best of standard practice is adequate but definitely required to produce shielding concrete with the specified density and uniformity.

BIBLIOGRAPHY

1. S. Glasstone, M. C. Edlund, "The Elements of Nuclear Reactor Theory" (D. Van Nostrand Company, Inc., New York, N. Y., 1952)
2. H. M. Glen, *Civil Engineering* **21,** 657 (1951)
3. V. Delano, C. Goodman, NP-1244 (1949)
4. E. Creutz, K. Downes, *J. Appl. Phys.* **20,** 1236 (1949)
5. P. C. Gugelot, M. G. White, *J. Appl. Phys.* **21,** 369 (1950)
6. R. B. Gallaher, A. S. Kitzes, ORNL-1414 (1953)
7. W. H. Price, *J. Am. Concr. Inst.* **26,** No. 1, 49 (1954)
8. Joint committee, "Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete" (Portland Cement Assoc., Chicago, Ill., 1940)
9. E. W. Tirpak, ORNL-1739 (1954)
10. T. C. Powers, T. L. Brownyard, *Research and Develop. Labs. Portland Cement Assoc. Bull.* No. 22, 295 (1948)
11. A. E. Pavlish, J. C. Wynd, AECD-3007 (1948)
12. M. J. Snyder, C. A. Burkart, J. W. Clegg, AECD-3004 (1949)
13. H. G. Harlow, P. R. Matthews, KAPL-901 (1953)
14. T. Rockwell III, ORNL-243 (1950)
15. L. P. Witte, J. E. Backstrom, *J. Am. Concr. Inst.* **26,** No. 1, 65 (1954)
16. H. P. Mittet, *The Trend in Engineering at the Univ. of Wash.* p. 14 (Apr. 1953)
17. U. S. Army Corps of Engineers, North Pacific Division Lab., Troutdale, Ore. (unpublished)

Reactor Vessels

Here's how the radioactive nature of the core affects design and fabrication of reactor containers. Although a reactor vessel needs greater structural integrity and reliability than a conventional vessel, radiation changes the metal's properties and induces higher thermal stresses in the vessel walls

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DESIGN AND FABRICATION of a vessel to contain the reactor core of a nuclear power system is complicated by several factors not encountered in most chemical or process vessels. As in conventional vessels, pressure, temperature, and corrosion resistance must be considered, but the unusual conditions introduced by the radioactive nature of nuclear core materials also must be taken into account.

Because the core's high levels of radioactivity create hazards and prohibit or seriously limit inspection and maintenance once the reactor has operated, reliability must be emphasized during design and fabrication. Dimensional tolerances are tighter than usual because of the need for careful core assembly and the importance of preserving fit and movability of mechanical parts. Although the fluids handled frequently are highly corrosive, outward leakage must be prevented because the fluids are radioactive, and inward leakage or lack of cleanliness could impair the nuclear properties of the core. High-intensity radiations from the core tend to damage the vessel material and increase thermal stresses. Underlying all these considerations is the need to preserve the nuclear integrity of the core assembly while minimizing costs and preventing leakage.

Radiation Damage

The new parameter of how radiation affects the physical properties of metals must be added to conventional considerations in pressure-vessel design.

Mechanism of damage. The collision of a high-energy neutron with the nucleus of an atom in the metal's crystalline lattice may dislocate the atom from its normal position and leave it entrapped as an interstitial atom. If the atom has acquired sufficient kinetic energy from the collision it may dislocate other atoms in the lattice. Accumulation of these displacements changes the material's properties.

Changes in mechanical properties. Exposure of carbon and stainless steels to radiation causes increases of up to 10–15% in yield and ultimate strengths and as much as 50% decrease in ductility at low temperatures. Changes are slight at high temperatures because the higher thermal energies of the atoms cause some of the interstitials to migrate, fill vacancies, and thereby remove the cause of damage.

There is a general increase in hardness that seems to approach equilibrium appreciably below the fully embrittled value. Annealed steels show proportionately greater hardening than hardened steels. The rate of hardening decreases with increasing temperatures.

There is a decrease in impact strength of carbon steels. Thus, extra care should be taken to eliminate sharp notches. The greatest decrease results from low temperature and high flux.

Stainless steel shows no significant change in fatigue strength, but density decreases slightly. Carbon steel's density seems unaffected.*

Some questions remain unanswered. Can materials be repaired by welding after being exposed to an intense radiation for an extended period? What will be the effects in the much greater fluxes of planned high-power reactors? How will intense irradiation affect corrosion rates?

Radiation Heating

The code for pressure-vessel design requires consideration of stresses due to pressure, mechanical loading, and thermal gradients.† But in the walls of a vessel for a nuclear reactor, scattering and absorption of neutrons and attenuation of gamma rays produce a new temperature gradient known as radiation heat.

An increase in wall thickness will reduce the pressure and mechanical-loading stresses but will increase the thermal stress. The maximum heat production due to gamma radiation occurs near the inner surface of the vessel and falls off exponentially toward the outside surface. The example in Figs. 1 and 2 indicates the magnitude of radiation heating and the induced stress that results.

* For details on how radiation affects metals, see NU, Sept. '54, p. 8.

† "Code for Design of Unfired Pressure Vessels," (American Society of Mechanical Engineers, New York, 1952).

An Example of Radiation Heating

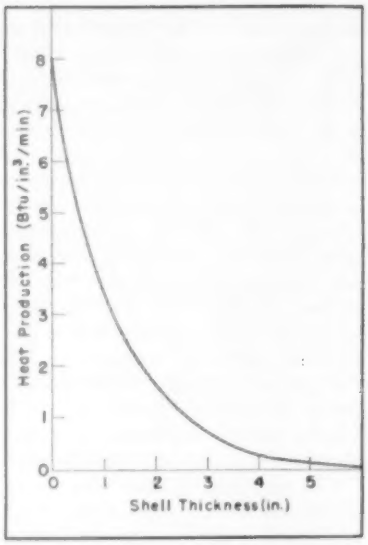

FIG. 1. Radiation-induced heat generation within the shell as a function of shell thickness is as shown here for a homogeneous-reactor core in a spherical carbon-steel pressure vessel of 6-ft i.d. subjected to a thermal-neutron current of 3×10^{13} n/cm²/sec and a gamma current of 5×10^{12} photons/cm²/sec in an energy spectrum of 1–6 Mev

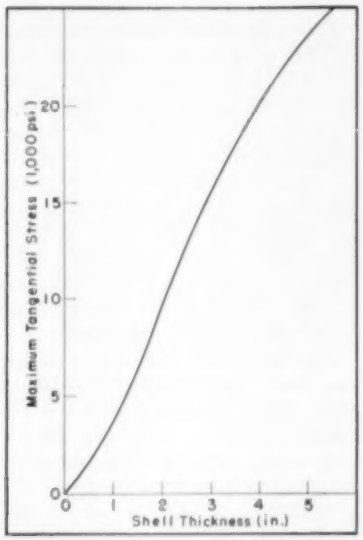

FIG. 2. Maximum tangential thermal stress as a function of shell thickness is as shown here if this example's spherical pressure shell is insulated on the outer surface in such a manner as to maintain the same temperature on the inner and outer surfaces so that the minimum thermal gradient through the shell is obtained

Besides using insulation to flatten the thermal gradient, stresses can be reduced by using one or more radiation shields within the vessel. These shields, of a dense material such as steel, reduce the intensity of radiation reaching the vessel wall. They are made in increasing thicknesses from the reactor core to the vessel wall, the thicknesses being determined by the thermal stress and the amount of cooling available.

The thermal stress in a pressure vessel is directly proportional to $\alpha E/k$, where α is the coefficient of expansion, E is the modulus of elasticity, and k is the coefficient of conductivity. Often stainless steel is employed for high-temperature systems containing corrosive materials. Unfortunately, the factor $\alpha E/k$ for stainless steel is 2–3 times that for carbon steel, which means 2–3 times higher thermal stress. Relief from this problem is found by using carbon steel clad with a relatively thin layer of stainless steel.‡

‡ For a more complete discussion on radiation heating in pressure vessels, see: R. H. Chapman, Analysis of spherical pressure vessel having an energy source within the wall, ORNL-CF-54-10-76 (1954).

Reliability

The special hazards entailed by the heat energy in a reactor core and the potential damaging effects of accumulated fission products magnify the need for dependability. A reactor vessel that has contained an active core often is unapproachable, and periodic examinations from close range usually are impossible. Thus, any credibly potential cause of failure during the entire 20–30-yr desired life of the vessel must be eliminated during design and manufacture. Only materials and designs thoroughly tested for reactor applications can be used safely.

Failures are rarely experienced in pressure vessels in other industries. When they do occur they are usually in the form of small cracks in the walls of pipes or in welds containing slag inclusions, porosity, or other imperfections, and usually result in seepage of the fluid. This leakage is almost always detected by regular visual inspection and is corrected before it reaches serious proportions. But in a nuclear system, detection of similar leakage may come too late to prevent serious consequences.

Corrosion

The difficulty of inspecting reactor systems internally makes the corrosion resistance of the vessel material of vital importance. Release of corrosion products into the reactor coolant system can have harmful effects on the cooling of the fuel, on the performance of the heat-exchanger equipment, and in the distribution of long-lived radioactive particles to other portions of the system. These harmful effects may limit the permissible corrosion rates in the reactor vessel to extremely low levels. Many of the most promising coolant fluids from the heat-transfer standpoint are not acceptable because of their corrosive attack on reactor-vessel materials.

The concern with corrosion has precluded the use of carbon and low-alloy steels for reactor materials if they are exposed to reactor coolant. This has resulted in widespread use of stainless steels for all components in the reactor system. To cut costs and to retain the structural advantages of carbon and low-alloy steels, these materials have been clad with a thin layer of more corrosion-resistant material. Considerable success has been achieved with clad steels of both the rolled and spot-welded types.

The same conditions that dictate high corrosion resistance in a reactor operate to enforce strict cleanliness specifications in the fabrication of the reactor container.

Leaktightness

Because of the radioactive nature of a nuclear heat source, containment of the core must be complete. An uncontrolled leak cannot be tolerated because, if inward, it might have adverse effects on the nuclear system, and, if outward, the release of radioactive materials would be hazardous.

In most systems zero unrestrained leakage is mandatory. This usually means a completely welded system

Vessels for Pressurized-Water Reactors

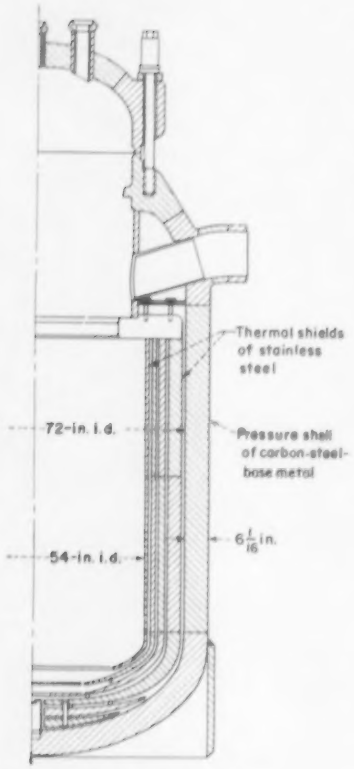

FIG. 3. Vessel for a typical pressurized-water reactor

Pressurized-water reactors are cooled by circulating water at pressures high enough to prevent boiling in the hottest regions. Because reactor-coolant outlet temperature will influence the thermal efficiency of the system, it is desirable to have maximum possible reactor coolant temperature. These considerations require extremely high pressure (800–2,500 psi) in the reactor vessels. The size of a critical core, the flow channels and the radiation shields dictate a vessel larger than about 4 ft in diameter.

Generally, pressurized-water reactors with their relatively low temperatures and high coolant pressures require thick-walled containers. These are particularly susceptible to thermal stresses where flexibility of operation is required. Use of high-strength steels sometimes provides means for construction of vessels for high-pressure service without the excessive penalties imposed by thick walls.

The use of solid stainless steels is not widespread in construction of pressurized-water reactors. This is mainly because of the higher cost of the alloy material. Figure 5 shows that stainless steels, in spite of their higher strengths at room temperature and at temperatures approaching 1,000° F, are assigned lower design stresses in the range for which pressurized-water systems are practical.

The necessity for corrosion resistance on the primary face prohibits the use of carbon steel here and use of solid stainless steel would require thicker walls and a heavier vessel. The fabrication and welding of stainless in these heavy walls presents more difficulty than does the fabrication and welding of equivalent plate thickness of carbon steel. Use of carbon steel base metal with a tightly bonded inner face of stainless steel presents a satisfactory compromise. The stainless-steel radiation shields are supported from the vessel shell in such a manner that the differential expansion at elevated temperatures is not harmful.

The solid fuel elements must be replaced periodically; thus the vessel must permit access to the core. The method of sealing the closure against the high pressures is of major concern. Large masses of steel, frequently used as high-pressure plugs in other industrial pressure vessels, cannot be used here since they are subject to severe radiation heating and thermal stresses during transient operation. Most vessels for reactors of this type have been constructed with bolted closures, very carefully designed to eliminate massive metal sections.

Vessels for Aqueous Homogeneous Reactors

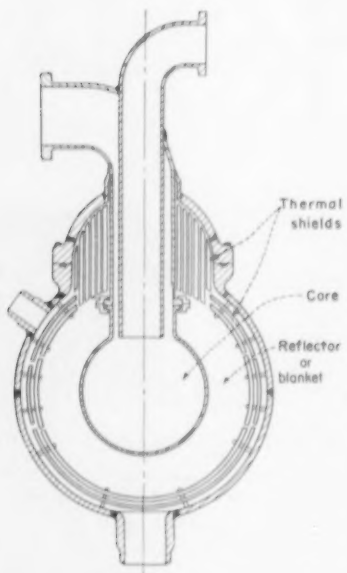

FIG. 4. Vessel for a typical aqueous homogeneous reactor

Aqueous-homogeneous-reactor vessels are usually spherical in shape because: (a) Nuclearly, a sphere is the optimum shape for core and reflector; (b) a pressure vessel can be made thinnest as a sphere, and this aids in reducing the thermal stress.

The operating pressure of a nonboiling-aqueous-homogeneous reactor is above 600 psi to minimize void formations that would result in some instability and loss of reactivity.

The core and reflector are separated by a container that is: (a) of corrosion-resistant material, to withstand the highly corrosiveness of the fuel-solution; (b) thin, to reduce neutron absorption and to minimize stresses due to induced temperature gradients from nuclear radiation and heat flow; (c) of a material that has a low neutron-absorption cross section, to reduce neutron loss between core and reflector.

Because of design requirements for higher-power homogeneous reactors, the pressure vessels are fairly large and are subjected to high pressures. These factors result in heavy-walled construction. Because of the thermal stress problems present with thick walls, it is especially important that protection be provided from the intense gamma and neutron radiation from the core. Such protection is provided by installing a series of radiation shields within the vessel to reduce the intensity of radiation reaching the vessel walls.

To minimize the thickness of the pressure vessel, carbon steel usually is used for the base material since the allowable stress for carbon steel between 300 and 750° F is greater than for the stainless alloys, as shown by Fig. 5. Corrosion protection for the interior surface of the vessel is obtained by bonding a layer of stainless steel to the carbon steel.

since this requirement presently cannot be met with normal gasket or packing-gland seals.

Selection of the type of seal will depend on desired frequency of access, restrictions imposed by potential personnel hazards, reliability required of the system, and economics of both materials and methods of fabrication.

Controlled outward leakage may be permitted only if it does not contaminate inhabited areas. One way to eliminate contamination is to collect the effluent in a closed bleedoff system.

Tolerable leakage may be from a few cubic centimeters per week to a few gallons per hour, depending on the size of the system, the hazards from the leaking fluid, and the capacity of the leak-disposal system.

Pressurized buffer seals for controlled inward leakage hold a possible solution to the sealing problems in gaskets or packing seals used with closures and shaft penetrations. The pressurizing fluid must be compatible with the reactor system and not objectionable in outward leakage past secondary seal.

Fabrication

Application of appropriate dimensional tolerances, practical restrictions on size, and use of the boiler code are important considerations in design and fabrication of reactor vessels. Figures 3 and 4 show vessels for two types of reactors. Each vessel must have supports designed to hold the weight, withstand all piping expansion forces, and accommodate the temperature expansion of the vessel.

Tolerances. Dimensional tolerances on reactor vessels usually are much more stringent than on most industrial pressure vessels. For example, the American Society of Mechanical Engineers (ASME) pressure-vessel code specifies that the out-of-roundness of a cylindrical shell shall not be more than 1% of the diameter. Thus, the 72-in. i.d. of the pressurized-water boiler in Fig. 3 could be out of round by ¾ in. If this were permitted, the coolant annulus between the shell and the thermal shield would disappear and the reactor core elements might interfere with the thermal shield. Thus, after welding and machining, re-rolling to a round shape sometimes is required.

Control rods must be aligned with the core matrix and support plates, and with the control drive bearings. This alignment requires special jigs and fixtures for locating each bearing or sleeve.

Permissible tolerances may be one-tenth the usual standard commercial practice for pressure vessels and boilers. These closer tolerances greatly increase fabrication time and cost. Thus, although the tolerances must be rigid enough to permit assembly and to prevent malfunction of mechanical parts, unnecessary limits should be avoided.

Limitations on size and thickness. Reactor vessels normally are completely fabricated in the manufacturer's shops and shipped to the jobsite by rail. The maximum sizes are limited to the railroad shipping clearances. Any vessel more than 11 ft in diameter must be checked with the carriers to determine what routes, if any, can handle this size. Units above 13 ft in diameter usually will require some field assembly. Field erection and welding of vessels more than 1 in. thick is apt to be expensive, and X-ray and stress relief are difficult at the jobsite.

Practical maximum fabricating thicknesses for vessel walls are limited to about 4 in. for stainless steel and 7 in. for carbon steel when made of plate material. The limitations are determined by difficulties in obtaining sound plate, forming into shells, and welding and X-raying seams.

Use of the ASME boiler code. Reactor vessels should be designed in accordance with the code's requirements. But radiation heating, radiation damage, and other problems unique to nuclear service are not covered by the existing codes. These problems must be resolved by special studies and tests and the results incorporated in existing codes or in special standards. ASME is studying problems peculiar to nuclear applications and is expected to recommend special rules soon.

Vessels for Liquid-Metal Reactors

Liquid-metal reactors have low pressures and high temperatures. The high temperatures and the good heat-transfer properties of the liquid metals induce severe temperature gradients that account for a major portion of the total stress in the container walls. Low pressure would permit thin walls, but the decrease in material strength at high temperatures counteracts this. Major difficulties are caused by system transients inducing large thermal gradients in the vessel. Special care must be taken to design flexibility into the reactor to provide for differences in thermal expansions of reactor components.

Corrosion and erosion in a liquid-metal system are major problems imposing severe restrictions on the materials that can be used safely with a particular coolant. For example, stainless steel, which seems suitable for handling sodium and sodium-potassium coolants, is not suitable for bismuth.*

The toxicity, highly radioactive nature, and the chemical activity of the liquid metals emphasize the need for reliability of equipment containing these fluids.

* Information on compatibilities of many liquid metals with commonly used materials can be found in: R. N. Lyon, ed. "Liquid Metals Handbook" (U. S. Government Printing Office, Washington, D. C., 1952).

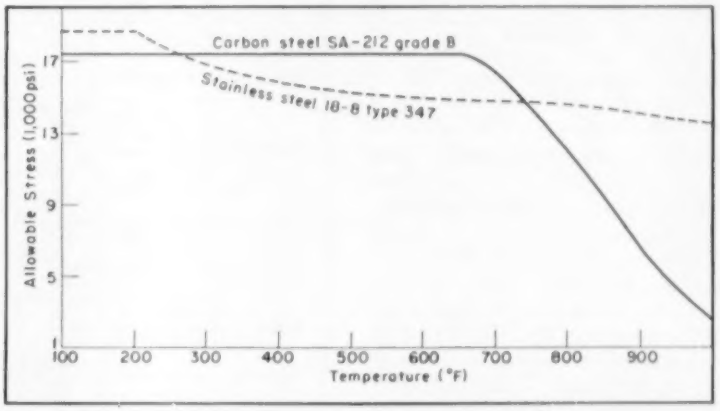

FIG. 5. How temperature affects allowable design stresses for a carbon steel and a stainless steel, according to the ASME boiler code

Construction of the SRE Core

Here's how the core of the Sodium Reactor Experiment is being built. Description of the arrangement of the fuel, graphite, sodium flow, and core enclosures provides background for understanding the methods used to make the zirconium-canned moderator-reflector units

By R. L. OLSON
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INTENDED AS a 20-Mw (heat) pilot prototype for power reactors of the sodium-graphite type, the Sodium Reactor Experiment is being built at Santa Susana, California. It is scheduled for testing in 1956. Use of graphite moderator and sodium coolant, together with the need for interchangeability of experimental core components, results in a subdivided core in which low-enrichment uranium-metal fuel rods are located in the core assembly as shown in Figs. 1 and 2.

To limit the amount of graphite that could absorb any sodium that might leak through a thin-walled fuel-channel, the graphite assemblies are individually canned as shown in Fig. 3. These moderator-reflector units can be removed from the core and replaced with alternate experimental units.

Fuel, moderator, reflector. The 6-ft-long fuel rods, which are suspended in assemblies from plugs in the top shield, hang within as many as 57 zirconium tubes lining the inside of vertical holes through the centers of the graphite moderator stringers. Thimble tubes for control and safety elements extend downward from the top shield and fit into 17 3.21-in.-i.d. channels formed by the scalloped corners of three adjacent moderator cans.

The moderator volume is 6 ft high, 6 ft in diameter, and is surrounded by a graphite reflector 2 ft thick. Thus, over-all dimensions of the graphite assembly are 10 ft high by 10 ft in diameter. This moderator-reflector core assembly consists of 91 vertical hexagonal graphite prisms or "stringers" and 28 stringers that are less than full hexagons, as shown by Fig. 2. Each hexagonal stringer is about 11 in. wide across the flats and is "canned" in a zirconium sheet-metal envelope.

Between the reflector and the core tank is a type-304 stainless-steel liner that serves as a baffle to reduce temperature gradients along the tank wall.

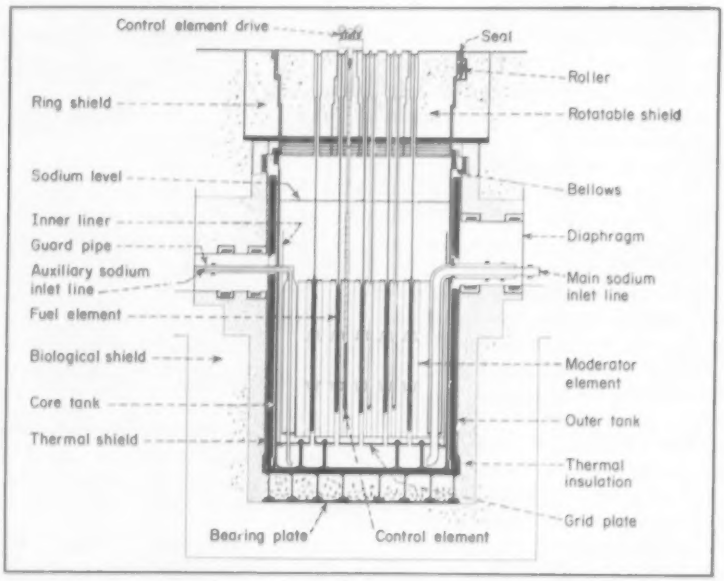

FIG. 1. SRE core, showing arrangement of fuel, moderator-reflector cans, coolant flow, containers, and control drives. Drive mechanisms fastened to outside of loading face actuate control elements through shield plugs, which form upper end of control-element thimbles. Both the core tank and outer tank assembly are welded, gastight, to upper shield through large stainless-steel bellows that accomodates vertical expansion of tanks. Two gallery seal boxes extending from outer tank assembly at level of sodium piping complete secondary envelope around expansion sections in upper portion of downcomer assemblies and discharge piping

Coolant flow. Sodium coolant at 500° F enters the core from downcomers into the plenum in lower head of core tank. It flows upward through fuel channels and into discharge pool above core. A smaller downcomer pipe supplies sodium to underside of core from where it flows upward in control channels and clearance spaces between cans. About 1,200 gpm of Na passes through the core; its mixed mean outlet is at 960° F. The inlet downcomers are concentric doublewalled pipe as-

semblies; the outer pipe is welded to the core tank wall; the inner sodium pipe joins the external sodium system just above upper reflector. A gas-filled annulus thermally insulates inlet sodium from sodium in core. There are a minimum number of critical welds in the sodium system at the core.

Reactor enclosures. The 49,000-lb type-304 stainless-steel core tank, which contains the moderator-reflector assemblage, fuel, and sodium coolant, has a 1½-in. wall and is 18 ft 10⅜ in. high with an 11 ft i.d. Its flat lower head supports a grid plate, which in turn supports the canned graphite.

The core tank is supported from below by the outer tank assembly, a flat-bottomed low-alloy steel (SA301 Grade B) vessel that provides a secondary envelope around the core. Shear lugs inside the bottom of the outer tank engage a slotted skirt on the core tank and allow for radial expansion while fixing the location of the core tank. Seven mild-steel rings, 138 in. i.d. by 5½ in. thick with a total weight of about 176,000 lb, stacked in the annulus between the core tank and the outer tank serve as thermal shields.

The outer tank is supported on a series of concentric cylinders that carry the core loads from the bottom of the core tank to circular bearing plates bolted to the reactor foundation slab. The cavity formed by the concrete foundation slab and side shield is lined with ¼-in. mild-steel plate. Actually, a core cavity-liner vessel with attached cooling coils is erected on the foundation slab and the side-shield concrete is poured against it. The spaces between the sides and bottom of the outer tank assembly and the cavity liner are filled with thermal insulation blocks.

Installation of the ring shield and loading-face shield completes the core enclosure. The underside of the loading face shield has a series of parallel, stainless steel, reflective-insulation sheets. All concrete facing the core contains cooling coils.

Fabrication

The methods used for making the zirconium hexagonal cans result from the close tolerances on the cross-section dimension, the limited width of the zirconium sheet readily available, and the desire to minimize cost and development time for tooling.

When tool fabrication was started, the tolerance on width across flats was

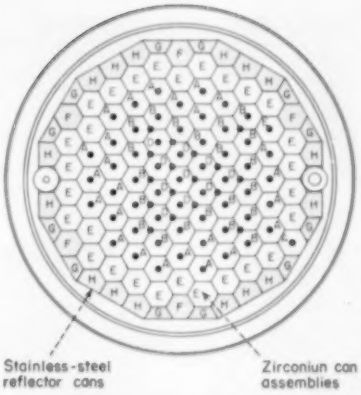

FIG. 2. Core arrangement of 86 zirconium-can graphite units of four types and 33 stainless-steel-can units of three types. Stainless-steel cans are used in outer reflector region where steel's greater neutron-capture cross-section does not appreciably affect fuel-enrichment requirements. Fuel rods hang in holes through centers of hex units; control and safety rods move in channels at corners of three adjacent cans

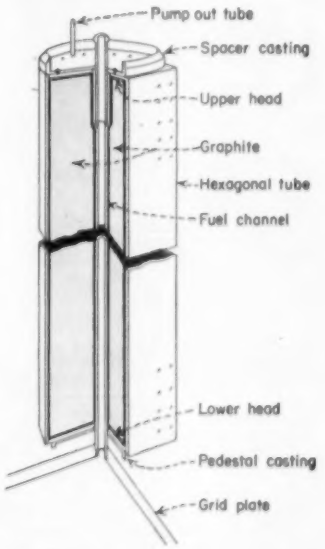

FIG. 3. Type-A can assembly uses a graphite stringer, 0.035-in.-sheet Zr for hexagonal tube, 0.10-in. Zr plate for upper and lower heads, 2.875-in.-o.d. × 0.035-in.-thick Zr tube for fuel channel, ½-in. o.d. × 0.035-in.-thick Zr for pump-out tube used to charge assembly with pressurized helium. Each can is supported on a grid plate by a type-304 stainless-steel pedestal casting, the flange of which is fastened to the lower head of can with 10 studs welded to can head. Upper ends of cans are spaced laterally by similar castings. Without pumpout tube, over-all height of unit is 120$^{7}/_{32}$ in.; outside width across flats is 10.872 in Unit weighs 760 lb, of which Zr is 49 lb. Stainless-steel sheet 0.031 in. thick is used for the hex walls of the outer reflector units

±0.015. Later analysis relaxed this to ±0.026. The close tolerance results from heat-transfer limitations between the graphite and the can wall, and from the need for limiting the flow space between cans.

Experience in forming and welding stainless-steel and titanium sheet for aircraft and missile skins indicates more assurance of complying with design specifications and cost and time criteria if the hex tube of Zr is built by welding together several simple formed shapes rather than by the limited production of more complex shapes having fewer welds. Preliminary tests indicate high-quality zirconium welds can be achieved with available equipment.

Forming the Zr panels. Each hexagonal tube is built up from six separate panels as shown in Fig. 4. Final sizing of the panel is accomplished as shown in Fig. 5. The power brake presses dimples into the panel to insure clearance for sodium flow in case can warps during reactor operation. The straight-break panels are folded in break dies that are heavier than normal.

Building the tubes. The panels are welded into a hexagonal tubular sheath as shown in Fig. 6. Argon shielding gas (16 ft³/hr) is introduced around the electrode and to cover the welded area behind the electrode. A grooved copper chill strip is inserted along the stake top and helium backup gas (3 ft³/hr) is introduced through ports drilled in the botton of the groove. All welds are inspected using both die-penetrant and radiographic techniques.

Assembling the can. Limitations on size of available reactor-grade graphite require that each moderator or reflector stringer be prepared from three blocks. The fuel channel in the center of the graphite block is bored to a diameter of 2.920 +0.010/−0.000 in., machined across flats to 10.755 ± 0.010 in., and the ends are finished selectively to make a 10-ft stringer. Then the stringer is moved horizontally into the hex sheath.

Can heads with attached studs and

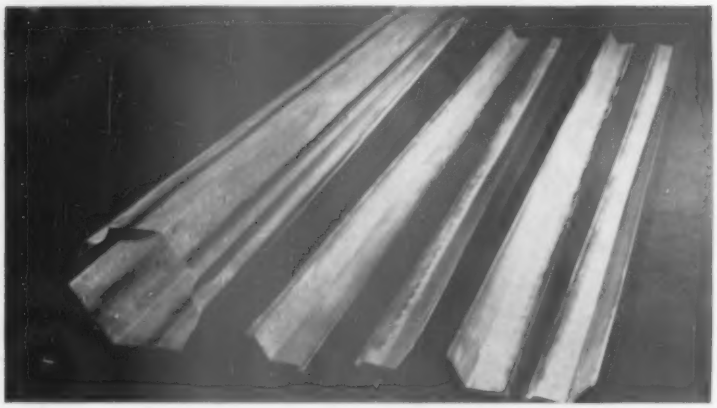

FIG. 4. Zirconium tubes are each built from six pieces made as "straight-break" panels or "scalloped" panels. Panel preparation begins by blanking 0.035-in. stock into strips 6.5 in. wide by 124 in. long. Tool pin holes are punched on ends of blank in sections later trimmed off. After panel is formed at room temperature with profile dies in power break, panel is clamped in stress-relieving fixture accurately machined to desired shape. It is held at 1,040° F for 15 min and permitted to cool in fixture. The slight oxidation is removed by blasting with fine alumina

FIG. 5. Longitudinal edges of panels are planed to desired dimension with an alloy steel cutting tool used dry with a 3-deg clearance angle and 67-deg lip angle. Cutting speed of 40 ft/min produces very satisfactory results

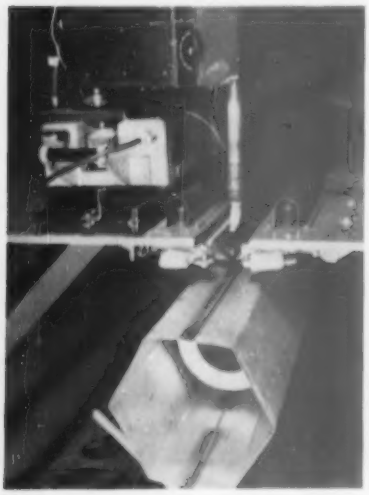

FIG. 6. Fixture and welding machine are used to form six panels into tubular sheath. Edges to be welded are cleaned by lightly buffing with emery cloth and wiping with acetone on an absorbent tissue. First part placed on stake is positioned to weld centerline by indexing planed edge with a locating gage. Mating part is butted to planed edge and held by clamps with 65-psi air. The 10-ft butt welds are made by power-driven automatic welding head moving at 4 in./min while stake or backup bar locates and supports panels and subassemblies. Welder uses tungsten electrode $\frac{3}{32}$ in. in diameter, tapered to sharp point over $\frac{1}{16}$ in. of tip. Starting tabs are either integral extensions of panel or tack-welded in place. High-frequency current is used to strike arc, then cut out as arc voltage is established at 10 volts for 40 amperes d-c, straight polarity. Wide range of settings give sound welds

the fuel-channel tube are fitted and manually welded in place using inert-gas-shielded tungsten arc. The welds joining the heads to the 0.035-in. material are run at about 8 in./min with a current of 60–70 amperes. The assembly sequence and the pumpout tube enable all welding to be backed up by inert gas.

After assembly, the can is leaktested with a helium mass spectrometer. Welds are inspected radiographically and with die penetrant. The completed can assembly is purged with helium, and the pumpout tube is pinched off and sealed by welding. The stainless-steel pedestal and spacer castings are assembled to the can heads using an alignment fixture to assure concentricity, and the stud nuts are secured with lock wire.

Putting cans into core. The moderator-reflector cans will be installed in the tank after installation of the core-tank bellows and ring shield.

After unpacking, final cleaning, and inspection in the reactor building, each can assembly will be lifted by the upper casting, lowered into the core tank, and fitted to the grid plate. The core assembly will proceed from the center and work outward. Careful gaging, checking, and recording of the center-to-center dimension of the units will insure proper fits under all conditions.

When the outermost cans are in place, adjustable locating bars fastened to the inside of the core tank at the elevation of the upper spacer castings will be set to girdle the core assembly. The top shield will be put in place by the 75-ton-capacity coffin-handling bridge and the core enclosure will be completed by sealing the joints.

Pilot production. Presently, we are completing a pilot quantity of cans to prove out or to indicate any necessary changes to the tooling and fabricating processes. This involves every step from material procurement to final assembly and testing. From this it has been determined that about 8,800 lb of zirconium ingot will be needed for cans for one core loading plus several experimental can units.

* * *

Many groups have contributed to the engineering analysis, development, test, design, and careful workmanship for the SRE core. These include the Materials Research and Process Development Group of the Aerophysics Department and the Tooling, Reactor Components and Sheet Metal Departments in the Los Angeles plant of North American Aviation, Inc.

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THE UN GENEVA CONFERENCE:

Condensing a World of Knowledge into 165 Hours, August 8 to 20

OVER A YEAR AND A HALF have elapsed since President Eisenhower first called, before the United Nations General Assembly, for international cooperation in atomic energy. Two months still remain before the international conference on peaceful uses, August 8–20, in Geneva, Switzerland. A lot has been done in the meantime to make this the largest exchange of nonsecret atomic energy information to date.

Actual triggering of the conference idea didn't occur until September 23, 1954, when Secretary of State Dulles first proposed it specifically to the General Assembly. On December 4, 1954, the General Assembly unanimously adopted a resolution calling for "an international technical conference of governments." From this point on, things have moved rapidly. World politics have played a minimum role; emphasis has been on making this the technical conference called for in the resolution. For example:

UN Secretary General Dag Hammarskjold's first action, three days after passage of the resolution, was to name Gunnar Randers as his special consultant. Randers, director of the joint Norwegian-Dutch atomic energy program, completed a "working party" to assist Hammarskjold. Other members are Ralph Bunche and I. Tchernychev, both members of the UN staff.

The advisory committee called for in the resolution, was made up primarily of top-flight scientists from the nations represented. It met in January and drew up a tentative program that opened with plenary sessions on world power needs and resources and proceeded to three-at-a-time simultaneous sessions on reactors and associated technology, radiation applications, and medical and biological uses. The committee also drew up rules of procedure that make it possible to curtail presentation of political papers and political discussion.

Between the time the advisory committee met in January and its next meeting in Paris on May 23, the UN Secretariat had to make definitive preparations for the conference. This was no small task. To do the job, the UN amassed a top-flight scientific staff headed by Walter G. Whitman (see chart on preceding page). Backing up this staff are the extensive organization and facilities of the UN—translators, interpreters, publications and other specialists.

Whitman, normally head of the department of chemical engineering at Massachusetts Institute of Technology and a member of the Atomic Energy Commission's general advisory committee, was named late in January. On February 1, Hammarskjold invited 84 nations to attend the conference and to submit papers for it. Deadline for submitting abstracts was set as May 15; actual papers were due July 1.

Abstracts Received

Almost 1,000 abstracts had been received from 17 nations by the deadline, and over 50 nations had accepted the invitation to attend. Both numbers can still rise; papers will still be accepted after the deadline, and lists of five-man delegations together with an unlimited number of official advisers (to present papers and participate in discussion) aren't due from participating countries until July 25.

Countries that have already indicated they will send delegations to the conference include: Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Burma, Byelorussian SSR, Canada, Chile, China, Cuba, Czechoslovakia, Egypt, Finland, France, German Federal Republic, Greece, Guatemala, Hungary, Iceland, India, Indonesia, Israel, Italy, Japan, Jordan, Korea, Luxembourg, Mexico, Monaco, Netherlands, New Zealand, Norway, Panama, Poland, Portugal, Romania, San Marino, Sweden, Switzerland, Syria, Thailand, Ukranian SSR, Union of South Africa, USSR, United Kingdom, U. S., Uraguay, and Yugoslavia.

Whitman predicts 700 or more delegates and advisers will attend.

How the UN Staff Works

Only a few abstracts came in during April; the flood peaked in the first two weeks of May. Thus it was good planning that Whitman's staff of scientific secretaries was completed and working together by May 2.

This group too is an indication of the scientific nature of the conference. Practically all of them work directly in atomic energy programs in their respective countries. Their backgrounds range from medical therapy to theoretical physics, but reactor design and isotope applications predominate.

The major concern of this group is the papers submitted. In early May, the group met each morning in a windowless 35th-floor conference room in the UN's New York headquarters. On a large green blackboard was an outline of the sessions of the conference. Working together with a spirit of accomplishment and cohesiveness that is readily discernible, they discussed the abstracts and started to fill in the agenda outline. Thus Whitman was able to present preliminary plans to the advisory committee by May 23.

Principal problem was which papers to choose for presentation. One factor was maintaining some sort of geographical equilibrium, especially in the plenary sessions. In addition, less than half those submitted can be presented within the time limits. The remaining papers will, however, be published in the proceedings of the conference.

Just when the proceedings will become available isn't known. To offset the expected time lapse somewhat, it's likely that the scientific secretaries will prepare summaries of the papers that won't be presented. Each session would then include such a summary. And the scientific secretaries probably will also help the conference president prepare the over-all summary that is scheduled to close the meeting.

Conference officers. The president, or one of seven vice presidents, will preside at all conference sessions. Homi Bhabha was named as president in January; Hammarskjold named

W. B. Lewis (Canada), F. Perrin (France), D. V. Skobeltsyn (USSR), Sir John Cockcroft (UK), General B. C. deMattos (Brazil), and I. I. Rabi as vice presidents recently.

UN service groups. Behind this seemingly simple transition from abstracts being submitted to papers being presented lies a welter of work. Abstracts (and in the future, papers) received by Whitman's scientific staff had to be translated into the four official languages of the conference—English, French, Russian, and Spanish. Copies of abstracts had to be sent to each delegation represented on the advisory committee, and to nations that will attend the conference.

Translation is not an easy task; there's no completely up-to-date interlingual dictionary of atomic energy terminology. Thus one of the first tasks of the UN service groups was to set up such a glossary.

Even more difficult than translation is simultaneous interpretation. Delegates to the conference can hear the proceedings in any of the four official languages. To accomplish this feat, UN interpreters have been studying atomic terminology since February.

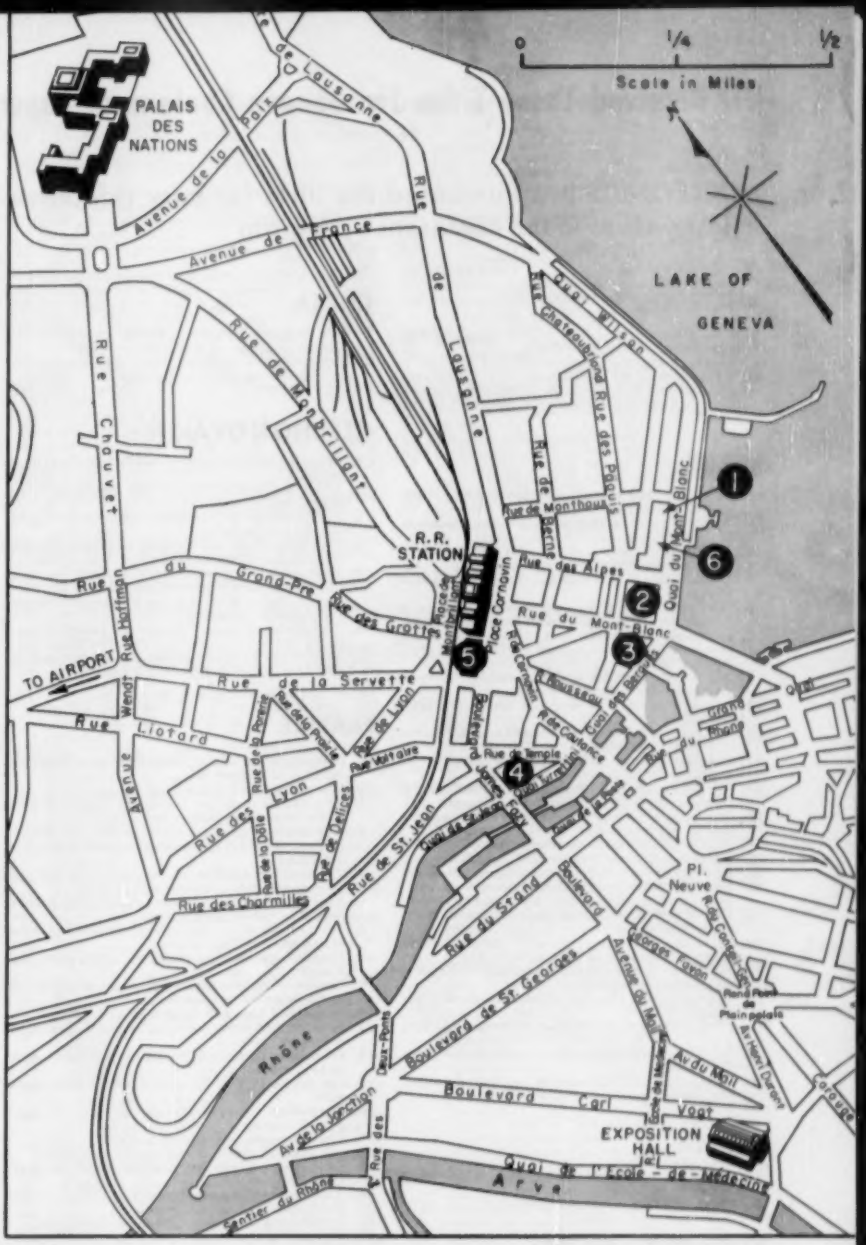
Finally, the proceedings will be published in all four languages. The problem here is whether a separate set should be published in each language, or whether each volume will contain four versions of its contents. As yet, no decision has been made.

Exhibits, Other Activities

Besides the conference program and proceedings, Whitman's group is also concerned with exhibits and with choosing evening lecturers to augment the program by discussing various aspects of atomic research.

Space for exhibits at the Palais des Nations, where the conference will be held, is limited. Thus the UN decided to restrict exhibits there to participating governments. Commercial and popular exhibits will be located at the exposition hall on the other side of the city; in April the UN announced that it had adopted a "hands-off" attitude and suggested that interested parties deal directly with the exposition hall.

At least five countries have asked for space at the Palais. Canada has asked for 500 square feet; France, 1,500; USSR, 2,200; U. S., 4,000; and the UK, 5,000. It's reported from one source that the downtown exposition hall has been deluged with requests for space—British firms alone have asked for 20,000 square feet, and the U. S. Information Agency will show its largest exhibit (NU, May '55, p. 22).



GENEVA, Switzerland, is site of international conference on peaceful uses of atomic energy. Conference sessions will be held in Palais des Nations, top left, which will also house government-sponsored technical exhibits. Industrial exhibits will be shown in exposition hall, bottom right, about four miles across city. Circled numbers show location of principal hotels: 1, Beau Rivage; 2, de la Paix; 3, des Bergues; 4, du Rhone; 5, Cornavin Garni; 6, Richmond. Map has been simplified; it shows only main streets

A U. S. industrial exhibit at the exposition hall is assured. Molesworth Associates, a New York public relations firm, contracted for 10,000 square feet; almost 20 firms will exhibit in that area.

Public attendance. The largest meeting room at the Palais can hold about 1,200 people. There will be little room for others besides members of delegations. But the meetings will be open to the public, and the UN is considering some sort of priority system so that those actually working in the atomic energy field can be given preference for the few public seats.

For a list of titles submitted to May 23, see page 76.

UN Received These Titles for Geneva Conference Papers by May 23

NUCLEONICS has numbered the titles for easy reference in later issues to the conference program

AUSTRIA

1. Austria's needs and possibilities for power and heat during the next 50 years
2. Natural occurrence of uranium and thorium
3. Memorandum on how atomic energy has been used for peaceful means in Austria during the last years and what program is intended for the future

BRAZIL

1. Brazilian plan of electrification and the possibilities of nuclear power
2. Areas of geologically probable occurrences of U and Th in Brazil
3. Known occurrences of U and Th in Brazil
4. Monazite in Brazil
5. Uraniferous Zr ores of the Pocos de Caldas Plateau
6. Occurrences of U associated with auriferous conglomerate in the Serra de Jacobina, Bahia
7. Stano-tantalo-uraniferous deposits and occurrences in the region of S. Joao Del Rei, Minas Gerais
8. Air survey applied to the search for radioactive minerals in Brazil
9. Extraction of Th and U from Brazilian monazite
10. Chemical aspects of the uraniferrous Zr ores of Pocos de Caldas
11. Spectrochemical determination of Th in monazite
12. On the use of liquid nuclear emulsions for the titration of U from radioactive minerals
13. The perspectives of the use of Th for production of nuclear power
14. Studies on the nuclear photoeffect
15. Photofission cross section of U and Th
16. Radioactive method for marking mosquitoes
17. Use of radioiodine in demonstration of antithyroidian activity of thiouracil and thiourea
18. Use of P^{32} in study of distribution of P in bones and teeth
19. Method for cardiac output determination using red blood cells labeled with P^{32}
20. Statistics of the therapeutical uses of radioisotopes in Brazil
21. Economic significance of nuclear power for Brazil
22. Photofission cross section of natural U and Th
23. Iodine fixation in the thyroid as influenced by thiouracil
24. Deposition of P^{32} in osseous and dental tissues
25. Studies on the nuclear photoeffect

BURMA

1. Individual countries' needs and possibilities for power and heat
2. Unconventional sources of power

BYELORUSSIAN SSR

1. C^{14} in the study of chlorophyll biosynthesis
2. Co^{60} in the study of the role of cobalt as a plant micronutrient

CANADA

1. U prospecting in Canada—ground and aerial surveys
2. Canadian practice in ore dressing and extractive metallurgy of U
3. Electric power in Canada—regional forecasts in relation to nuclear power possibilities
4. Some economic aspects of nuclear fuel cycles
5. Experiments on some characteristics of the NRX reactor—Part I—methods and prolonged fuel irradiation
6. Experiments on some characteristics of the NRX reactor—Part II—temperature and transient poison effects
7. Experience with heavy-water systems in the NRX reactor
8. Health and safety activities in reactor operations and chemical processing plants
9. Further clinical studies of thyroid and salivary gland function with radioiodine
10. Studies of special problems in agriculture and silviculture by the use of radioisotopes
11. An economic forecast of the role of nuclear power in Canada
12. Waste disposal into the ground
13. Current techniques in handling and distributing Co^{60} radiation sources

CHINA

1. Role of nuclear power in China's power development program in the next 50 years
2. Exploration of monazite and associated minerals in the province of Taiwan

CZECHOSLOVAKIA

1. Measurement of soil moisture with neutron source
2. Remarks about the Milne problem with cylindrical symmetry
3. Prospects for utilization of atomic energy in the field of radiology
4. Significance of thermodynamic and electric factors for the economics of nuclear power
5. Prospects of power development in the Czechoslovak People's Republic and the corresponding role of the use of nuclear energy for peaceful purposes
6. Utilization of atomic energy for peaceful purposes in the Czechoslovak People's Republic
7. Report on the applications of radioisotopes in the Czechoslovak People's Republic

FRANCE

1. Utilization of radioisotopes in France in medical and biological fields
2. The problem of radon in U mines
3. The problem of the biological action of low doses of ionizing radiation
4. Restoration studies after partial or total-body irradiation by ionizing radiation and by beta rays
5. Metabolism studies of leavening in baking with radioactive glucose and ethanol
6. The contribution of anticipated future occurrences in the field of energy
7. Integration of nuclear energy into the means of energy production
8. Regulation of radioisotope utilization in France
9. Statistics on production and use of artificial radioelements in France
10. Industrial use of radioelements in France
11. Recovery of energy produced in G1, graphite air-cooled reactor
12. Dynamic problems of power reactors and analog machines
13. Complete automatic control of nuclear reactors
14. Detecting ruptures of the sheath of gas-cooled reactors
15. Dual-purpose G2 reactor project
16. Methods of research and study of U ores
17. Chemical process for treating minerals poor in U
18. Two cases of physical treatment of U minerals
19. Preparation of pure U metal
20. Production of nuclear graphite in France
21. Amount of traces of boron in graphite, U and Be
22. Loss of Be oxides
23. Process for separating Zr and Hf
24. Passage of heavy water in reactors
25. Study of U-Al alloys
26. Measurement of atmospheric radioactivity and pollution near an atomic center
27. Measurement of cross sections of fissionable nuclei for slow neutrons
28. Study of the variation with energy of fission cross sections of U^{233}, U^{235}, and Pu^{239} for fast neutrons
29. Time-of-flight spectrometer for slow neutrons in use at the Saclay pile
30. Study of slowing down of neutrons in graphite
31. Measurement of neutron diffusion length in glucina
32. Neutron study of two heavy-water piles
33. Radiation-induced changes in nonmetallic materials and thermal retrogradation of these changes
34. Role of O in reactions produced in aqueous solutions by ionizing radiations
35. Research on the etiology of congenital myxoedeme
36. The exploration of the thyroid function by radioiodides
37. The dangers of irradiated U in nuclear reactors
38. Influence of Co^{60} gamma rays on two immunity factors: phagocytic capacity of leucocytes and the formation of serum antibodies
39. Utilization of sulfites by higher animals
40. Separation and determination of iodized amino acids and of thyroxin by means of anion exchange resins
41. Distribution kinetics of radiosodium in rabbits in high-temperature environs
42. Dissolution of slightly soluble phosphates in the presence of an ion exchanger, studied by isotopic dilution
43. Study of the spermatogenesis of domestic animals with P^{32}
44. Observations on pollenization of the lucerne
45. Radiation-excited X-rays: application to thickness measurement
46. Radiography with the aid of bremstrahlung
47. Scintillation dosimetry of very intense radiation
48. Dosimetry of Co^{60} radiation and thermal neutrons in heavy-water piles
49. The Saclay reactor: two year's experience with heat transfer by compressed gas
50. Uranium ores in France and in French overseas territories
51. Examples of activation analysis
52. Production of pure Be oxide
53. A solvent process for extracting Pu from U irradiated in reactors
54. A method for extracting U^{233} starting from Th irradiated in a reactor
55. Spinning of U in gamma phase
56. The testing of materials by the oscillation method at the Chatillon reactor
57. Determination of thermal-neutron mean-free-path in a solid or liquid medium starting from a measurement of a complex diffusion length
58. Chemical reactions initiated by ionizing radiations in various organic substances
59. Photographic method for determining the location of a radioactive body in an organism
60. Use of the betatron for treating oesophagic and bronchopulmonary cancers
61. Use of colloidal radiophosphate of chromium in treatment of malignant tumors
62. Use of tritiated water as an indicator of water metabolism in normal subjects and atomic energy workers

INDIA

1. Need for power in India during the next 30 years and the possibilities of the economic use of atomic power
2. Thermal inelastic scattering of cold neutrons in polycrystalline solids
3. An ion-exchange process for the recovery of U from carbonate leach solutions
4. Determination of diffusion constants of moderators using pulsed neutron sources
5. Beneficiation characteristics of uraniferous ores in India
6. Natural occurrences of U and Th in India
7. Separation of Hf from Zr by vapor phase dechlorination

ISRAEL

1. Energy requirements of the State of Israel
2. Measurements of natural-water sources as aid in prospecting for underground deposits of U
3. The design of isotope separation plants: some basic design equations for the distillation process
4. Application of C^{14}-labeled substances in the study of adipose tissue metabolism
5. Medical use of radioisotopes in the Radium and Tumor Institute, Hadassah University Hospital, Jerusalem

ITALY

1. Italian power requirements in 1975 and 2000
2. Role which nuclear energy can play in Italy as an energy source during the next 50 years
3. Present state of uranium surveys in Italy
4. The first Italian nuclear reactor: principles of the project and technical characteristics

NORWAY

1. Needs and possibilities for power and heat in Norway during the next 50 years
2. Occurrence of U and Th in Norway
3. Preliminary study of an experimental pressurized heavy-water reactor
4. Production of D_2O in Norway
5. Corrosion of Al alloys at high temperatures in aqueous solutions
6. Radiation damage in U metal
7. Radiation from short-lived fission products
8. The measurement of resonance integrals of U with reactor oscillator
9. Distribution of resonance neutrons in a heavy-water natural U lattice
10. Studies in fine structure of fission yield
11. Genetic effects of radiation
12. Industrial uses of isotopes in Norway
13. Separation of carrier-free isotopes by diffusion methods
14. Enzyme destruction

15. Isotope applications in medicine
16. Energy consumption in Norway
17. Cysteamine-cystamine: On the mechanism for the protective action against ionizing radiation
18. Preliminary study of an experimental pressurized heavy-water reactor
19. Corrosion of Al and Al alloys in aqueous solutions at high temperature
20. Distribution of nuclear charge in low- and high-energy fission
21. Some industrial uses of radioisotopes in Norway
22. Measurements of effective resonance integral of U with pile oscillator
23. Angular correlation of fission neutrons
24. Notes on stability of fuel elements
25. Separation of carrier-free isotopes by diffusion methods
26. On the occurrence of U and Th in Norway
27. Practical experiences with JEEP
28. Effects of gamma rays on growth and sprouting in carrots and potatoes during storage
29. Genetic effects of chronic gamma radiation from Co^{60} in plants
30. High-energy gamma rays from short-lived fission products

SWEDEN

1. Sweden's needs and possibilities for power and heat
2. The natural occurrence of U and Th in Sweden
3. Chemical treatment of low-grade ores and ore concentrates of U and Th
4. Metallurgy of Th, U, and their alloys
5. Zero-energy, exponential and critical (or model) experiments
6. Reactor calculation techniques and comparison with experiments (including remarks on research reactors)
7. Radiation injury and protection
8. Utilization of nuclear energy in the resolution of special problems in agriculture and silviculture
9. Sweden's energy outlook
10. The occurrence of U and Th in Sweden
11. Swedish Atomic Energy Company—a cooperation between Government and private industry
12. Recovery of U from U-bearing alum shale
13. The extraction of U and Pu with tetrabutylammonium-nitrate, cupferron and neocupferron as complexing agents
14. Solid-state reaction between U and Al
15. Observations on the corrosion of U in liquid Na
16. Properties of electrostatic precipitators for the measurement of radioactive aerosols
17. Measurements on a suberitical reactor with a pulsed neutron source
18. Some experiences from measurements on an exponential pile of U and heavy water
19. Characteristics of the Swedish heavy-water reactor
20. Measurements of low-level radioactivity, particularly the gamma radiation from living subjects
21. Production of beneficial new hereditary traits by means of ionizing radiation
22. Studies on properties of an electrolytic cell consisting of an electrode system in a chloroform alcohol solution under gamma irradiation

UKRAINIAN SSR

1. Use of radioisotopes in the study of the analytical chemistry of Zr and Hf
2. Use of radioisotopes for research in the field of the functional biochemistry of the brain
3. Use of radioisotopes for research in the field of muscle biochemistry
4. Study of Co diffusion in Co-Ni-Mn alloys with the use of Co^{60}
5. Use of radioisotopes for the study of the wear of machine parts
6. Inelastic scattering of fast neutrons by atom nuclei

UNITED KINGDOM

1. Energy requirements of the U. K.
2. Contribution of nuclear power to U. K. energy requirements up to 1975
3. The behaviour of I^{131}, Sr^{89} and Sr^{90} in certain agricultural food chains
4. Radiological hazards from an escape of fission products and the implications in power reactor locations
5. Recent developments of radioisotope uses in industry
6. Tri-*n*-butyl phosphate as an extract-agent for the nitrates of the actinide elements
7. Radiation damage in nonfissile materials
8. Effect of radiation on heterogeneous systems of air or nitrogen and water
9. Some problems of radiotherapeutics
10. Control of radiation hazards in the operation of medium-powered experimental reactors
11. Development in thickness gages and allied instruments
12. Technical education and training of engineering personnel in the field of nuclear energy
13. The cost of power and the value of Pu from early nuclear power stations
14. Capital investment required for nuclear energy
15. The experimental animal for study of the biological effects of radiation
16. The rationale of an organised supply of tracer compounds
17. Importance of isotopes in biology and medicine
18. Long-term aspects of fission product disposal
19. Handling of high-activity gamma-ray sources
20. Administrative and legal problems of widespread use of high-level radiation sources—industrial health and safety. Radiological health-safety codes
21. The experimental facilities of E.443
22. The Dounreay fast-reactor project
23. The graphite-moderated gas-cooled pile and its place in power production
24. Production of U metal
25. Analytical methods
26. Methods of separation of Zr from Hf and their technological implications
27. Fundamental aspects of the corrosion of Al and their application to nuclear reactors
28. Applications of square-wave polarography to analytical problems from experimental reactor loops
29. Chemical principles in the separation of fission products from U and Pu by solvent extraction
30. Criteria for the selection of separation processes
31. Chemical processing of fission-product solutions
32. Alloys of U and Th
33. Heat-transfer experiments with Na and NaK
34. The measurement of dissipation of effluent in the sea (Part I)
35. The discharge of radioactive waste products in the Irish Sea, II. The preliminary estimate of the safe daily discharge of radioactive effluent
36. The discharge of radioactive waste products in the Irish Sea, III. The experimental discharge of radioactive effluents
37. Neutron spectrometers based on pulsed sources
38. Cross-sections of the Pu isotopes
39. Slow-neutron cross-sections of the U isotopes
40. Fission cross-sections as a function of neutron temperature
41. Neutron yields from fissile nuclei
42. Neutron capture in some coolant and canning materials in the intermediate energy range
43. Studies in the neutron resonance absorption of U^{238}
44. Plutonium-water critical assemblies
45. The experimental basis of lattice calculations
46. Method for calculating the critical mass of an intermediate reactor
47. Upper and lower bounds for critical size according to one-group theory
48. Long-term reactivity changes in natural-U reactors
49. Calculation of thermal utilization by the method of spherical harmonics
50. Neutron flux instrumentation systems for reactor safety and control
51. Emission of active rare gases from fissile material during irradiation with slow neutrons
52. The condition of fission-product iodine in irradiated U metal
53. The chemistry of Ru
54. An atomic energy radiochemical laboratory—design and operating experience
55. Some aspects of Po chemistry
56. The effects of irradiation on graphite
57. Damage occurring in U during burn-up
58. The absorption of vitamin B_{12} and the pathogenesis of B_{12} deficiency
59. The estimation of Ba and Sr in biological materials by activation analysis with special reference to the turnover of Sr in man
60. The genetic problem of irradiated human populations
61. Modes of radiation injury—medical aspects
62. Radiation injury and protection—maximum permissible exposure standards
63. Safety criteria in atomic energy
64. The criticality safety of chemical plant producing fissile materials
65. Recovery from radiation injury
66. Some recent applications of tritium in biological research
67. Studies on the incorporation of radioactive precursors into the nucleic acids and related compounds in living cells
68. The use of C^{14} in the study of biosynthetic processes
69. Some aspects of sucrose metabolism in plants
70. Factors affecting the availability to plants of soil phosphates
71. The production of beta-ray sources for industrial and clinical use
72. Application of radioisotopes to leakage and hydraulic problems
73. The development of gamma radiography
74. Recent developments in the irradiation of long-chain polymers
75. Survey paper on research reactors
76. Fuel cycles
77. Experimental studies on fast-neutron reactors at AERE
78. Infrared methods for the analysis of heavy water
79. Electronic configuration of the actinide elements
80. Role of nuclear energy in relation to other methods of electricity generation
81. Use of radioisotopes in diagnostic procedures
82. Stability conditions in the nonlinear dynamics of heterogeneous reactors
83. World's needs for a new source of energy
84. Radioactive mineral resources of Great Britain
85. Radioactive minerals in Central African Federation
86. Radioactive minerals in the British Colonies
87. Experience with BEPO
88. Instrumental developments in prospecting, mining, and chemical processing of nuclear materials
89. Methods of prospecting for U and Th
90. Characteristics of liquid-liquid extraction equipment as applied to radioactive processing
91. Determination of trace impurities in liquid-metal coolants by radioactivation methods
92. Slow-neutron spectrometers based on nuclear reactors
93. Speed of iodine metabolism
94. Recent advances in radioactivation analysis
95. Radioactive survey of the area surrounding an atomic-energy factory
96. Liquid-metal handling
97. Possible role of Th in nuclear energy
98. Comparative studies of the biological effects of radiation and of radiomimetric chemical agents
99. Chemical problems of power reactors

UNITED STATES

1. U provinces
2. Distribution of U occurrences in the U. S.
3. U in igneous rocks of the U. S.
4. U in magmatic differentiation
5. Distribution of U and certain other trace elements in felsic volcanic rocks of Cenozoic age of the western U. S.
6. U deposits in volcanic rocks of the Basin and Range Province
7. U-bearing vein deposits in the U. S.
8. Pitchblende deposits in the Central City district, and adjoining areas, Gilpin and Clear Creek Counties, Colo.
9. U deposits of the Boulder Batholith, Mont.
10. U in the fluorspar deposits of the Thomas Range, Utah
11. Wall-rock control of certain pitchblende deposits in Golden Gate Canyon, Jefferson County, Colo.
12. Relation of secondary U minerals to pitchblende-bearing veins at Marysvale, Piute County, Utah
13. Thucholite in vein deposits
14. U deposits at the contact of meta-sediments and granitic intrusives in the western United States
15. Relation of tectonic elements in precambrian rocks to U deposits in the Cordilleran Foreland of the western U. S.
16. Influence of regional structure and tectonic history upon the origin and distribution of U on the Colorado Plateau
17. Age and environment of U host rocks in the U. S.
18. Distribution of the chemical elements in sandstones and sandstone-type U deposits of the Colorado Plateau
19. Regional transmissivity of the exposed sediments of the Colorado Plateau as related to the distribution of U deposits
20. Relation of carnotite deposits to permeable rocks in the Morrison Formation, Mesa County, Col.
21. Direction of transportation of the sediment constituting the triassic and associated formations of the Colorado Plateau
22. Sedimentary features of upper sandstone lenses of the salt wash member and their relation to U-V deposits in the Uravan district, Montrose County, Col.
23. Significance of roll ore bodies in genesis of U-V deposits on the Colorado Plateau
24. U deposits in limestone
25. Guides to U deposits in the Gallup-Laguna area
26. U deposits in the shinarump conglomerate and the chinle formation on the Colorado Plateau
27. Channels and related swales at the base of the shinarump conglomerate, Monument Valley, Arizona
28. The Temple Mountain Collapse, San Rafael Swell, Emery Co., Utah
29. U deposits in the White Canyon area, San Juan County, Utah
30. U deposits in shoreline sandstones of terrestrial and marine origin
31. U in clastic rocks of the Basin and Range Province
32. U deposits in tertiary clastics in Wyoming and Northern Colorado
33. Geology and U mineral deposits of the Pumpkin Buttes area, Powder River Basin, Wyo.
34. Lithologic, structural and geochemical controls on U deposition in the Southern Black Hills, S. D.
35. Occurrence of U in diatremes of the Navajo-Hopi Reservation, Ariz., N. M. and Utah

(Continued on page 100)

Beta Emitters by Energy and Half-Life

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THIS TABLE can help identify unknown beta emitters whose half-life and beta energy have been determined by standard laboratory techniques. It also is a guide to beta-emitting isotopes for applications requiring specific half-lives and energies. (A similar table for gamma emitters is in preparation.) A more detailed compilation of nuclear data, such as National Bureau of Standards Circular 499 and Supplements, should be consulted for details of these emitters and their decay.

Emitters of conversion electrons and positrons as well as emitters of beta rays are included since all these particles produce similar effects when absorption methods are used to determine energy. Where an isotope can decay by emission of beta particles of different energies, the emitter is listed in the energy group corresponding to each beta, provided its contribution to total beta activity is greater than 5%. This is the lower limit of detection of typical absorption technique (Harley and Hallden, NU, Jan. '55, p. 32). All the betas from one emitter will lie in the same half-life interval.

Only isotopes with half-lives greater than 6 hr are listed; in general, a shorter half-life limits identification by the methods described.

Daughters with shorter half-lives than their parents are listed *in italic* under the half-life of the parent. In the natural series, the short-lived daughters are listed under the half-life of the nearest antecedent having a half-life over 6 hr. U^{237} (0.1–0.3 Mev, 5–10y) should be in italic.

* * *

All data used in this compilation are from National Bureau of Standards Circular 499, including Supplements 1, 2, and 3.

Half-life	E_{max} (Mev) 0–0.1	0.1–0.3	0.3–0.5	0.5–0.7
6–12 hr		Tm^{166} Bi^{204}	I^{135} Eu^{152} Ta^{180} Tl^{199} Pb^{212} Pa^{234}	Fe^{52} Zn^{62} Pd^{101} Er^{171} Ta^{180} Pb^{212}
12 hr–1 d		K^{43} Br^{76} Pd^{112} Pr^{142} Tb^{154} Au^{193}	I^{133} Ce^{139} Ir^{194} Np^{236}	Cu^{64} Ga^{72} Nb^{96} I^{130} Pt^{197}
1–3 d	Lu^{170} Ta^{177}	Zn^{72} Mo^{99} Ba^{135} Re^{184} Os^{193} Th^{231} Pa^{232} Np^{238} Np^{239}	Cu^{67} As^{76} Br^{77} Br^{82} Cd^{115} Sn^{121} Cs^{129} Tl^{200} Np^{239}	Sc^{46} As^{71} Ga^{72} As^{77} W^{187} Np^{239}
3–5 d	Tb^{157}	Te^{119} Te^{132} Eu^{145} Tb^{157} Yb^{175} Pt^{193}	Dy^{166} Yb^{175} Au^{199}	Sc^{47} Y^{87} I^{124}
5–10 d		Cs^{131} Tb^{153} Tm^{167} Lu^{171} Lu^{172} Lu^{177} U^{237}	I^{131} Xe^{133} Ho^{162} Er^{169} Lu^{177}	Mn^{52} I^{131} Cs^{132} Tb^{161} Pb^{209}
10–13 d	Ir^{190}	Ba^{131}	Ba^{140} Nd^{147} Pb^{211}	
13–15 d		Os^{191} Ra^{225}	Cs^{136} Eu^{149}	
15–20 d			Eu^{156}	
20–30 d	W^{179}	Th^{234} Pa^{233}	Ce^{141}	Ce^{141} Pa^{233}
30–40 d		Nb^{95}		
40–50 d	Rb^{103}	Fe^{59} Hg^{203}	Fe^{59} Ru^{103} W^{181}	Ru^{103}
50–100 d		S^{35} Nb^{95} Ho^{161} Tm^{168}	Sc^{46} Co^{58} Zr^{95} Sb^{124} Tm^{168} W^{185}	Sb^{124} Tb^{160} Ir^{192}
100–150 d	W^{181}	Ta^{179}		Ta^{182}
150–200 d		Ca^{45} Lu^{174}		Lu^{174}
200–250 d			Zn^{65}	
250 d–1 y	Ru^{106} Ag^{110} Tb^{158}	Co^{57}	Ce^{144}	Ag^{110}
1–2 y	Tm^{171}	Eu^{155}	Sn^{121}	
2–3 y	Cs^{134}	Sb^{125}		Na^{22} Sb^{126} Cs^{134}
3–5 y		Pm^{147} Lu^{172}		
5–10 y	Ra^{228} Pu^{241}	Eu^{154} U^{237}	Co^{60}	Cd^{113} Eu^{154}
10–20 y	H^3			
20–30 y	Pb^{210} Ac^{227}			Sr^{90}
30–50 y				Cs^{137}
50–100 y	Ni^{63} Sm^{151}			
>100 y	Pd^{107} Nd^{150} Re^{187} Ac^{227} Ra^{226}	C^{14} Rb^{87} Tc^{99} I^{129} Cs^{135} Th^{231} Pa^{230} Th^{234} Np^{236}	Am^{242}	Be^{10}

0.7–0.9	0.9–1.1	1.1–1.3	1.3–1.5	1.5–1.7	1.7–1.9	1.9–2.1	2.1–2.3	2.3–2.5	2.5–2.7	2.7–2.9	2.9–3.1	3.1–3.3	3.5–3.7	3.7–3.9	3.9–4.2
Ga^{66} Rb^{82} Te^{127} Sm^{156}	I^{135} Xe^{133} Er^{171} Ta^{178}	Se^{73} Sr^{91} Pa^{234}	I^{135} Er^{171}	Ac^{228}	Ga^{77} Tl^{208}	Tm^{166}	Pd^{101} Bk^{212}		Mo^{82}	Cu^{62}	Y^{93}	Sr^{91}			Ga^{66}
Zn^{69} Gd^{159}	Co^{58} Ga^{73} Y^{87} Pd^{109} I^{130} Eu^{157} Am^{242}	Rh^{100}	Na^{24} Co^{58} Ga^{72} Nb^{97} I^{133}	Nb^{90} Eu^{157}		K^{42} Re^{188}	Zr^{97} Ir^{194}		Ga^{73} Tb^{154}		Rh^{100}	Ga^{72} Br^{76}	K^{42} Ag^{112}		
Ni^{57} Rh^{105} In^{115} Sm^{153}	Ge^{69} Ga^{72} Cd^{115} Pm^{149} Au^{198}	Os^{193}	Sc^{44} As^{76} Sb^{122} Te^{131} La^{140} Ce^{143} W^{187} Np^{238}	Zn^{72} La^{140}	Ho^{166}	Sb^{122} Te^{131}	Y^{90} La^{140}		Cu^{66} Ga^{72} As^{76}	As^{72}		Ga^{72} As^{76}			
Te^{127} I^{132} Pb^{214}	Zr^{69} Re^{186}	Rb^{100} Sb^{129} Bi^{210}	I^{134}	Bi^{214}	Ho^{166}		I^{134} I^{132}	Pb^{140}			Rb^{100}	Bi^{214}			
	Ca^{47} Ag^{111}	Bi^{213}						Sn^{125} Pm^{148}		As^{72}	Sb^{118}				
I^{126} Nd^{147}	Ba^{140}	I^{126}	Nb^{92} La^{140} Tl^{207} Pb^{211}	La^{140}			La^{140}								
	Pr^{143}				P^{32}										
V^{48} As^{74} Rb^{86}	As^{74} Pa^{230}		Ta^{178}		Ru^{86}			Eu^{156}							
		Fr^{223}						Pa^{234}							
					Te^{129}										
				Y^{91} Cd^{115}		In^{114}									
Te^{127}	Sb^{124}		Co^{56} Sr^{89}	Sb^{124} Y^{91}				Sb^{124}							
Tm^{170}	Tm^{170}		Sn^{123}												
	Rh^{102}	Rh^{102}			Ga^{68}										
							Rb^{106} Ag^{110}				Pr^{144}		Rb^{106}		
Tl^{204}															
Kr^{85} Eu^{152}				Eu^{152} Ac^{228}	Eu^{154}										
		Bi^{210}					Y^{90}								
		Cs^{137}													
Cl^{36}	Al^{26}		K^{40} Np^{238}	Ac^{228}				Pa^{234}							

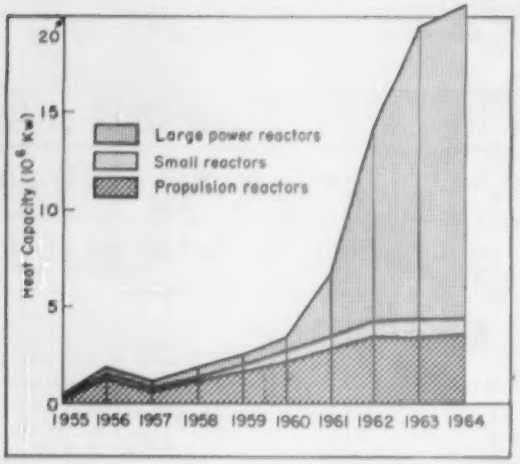

FIG. 1. Growth of nuclear power plant capacity (yearly additions)

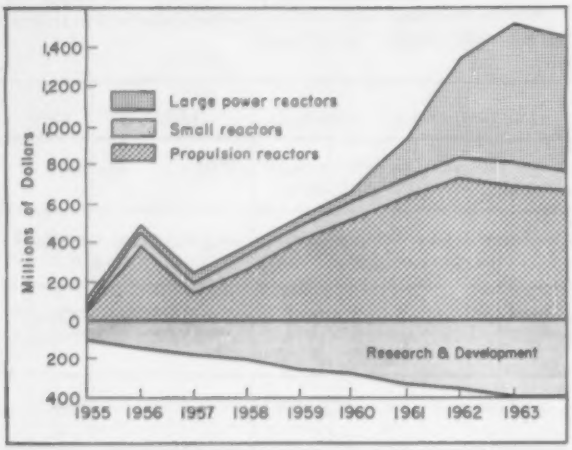

FIG. 2. Annual dollar volume of nuclear reactor plant expenditures and related research and development (yearly additions)

NUCLEAR POWER:
A Multibillion Dollar Business by '63

WITH ALMOST 800,000 KILOWATTS of electricity tentatively planned to be produced from nuclear power plants in the United States by 1960, there has been considerable speculation about what this and related activities mean in dollars and cents for the nuclear equipment industry. With the release last month of a report by the Atomic Industrial Forum, Inc., on "A Growth Survey of the Atomic Industry, 1955–65," a good basis now exists for evaluating market potentials.

The main conclusions of the Forum study are:

- By 1964, yearly additions of nuclear power plant heat capacity will jump from 1,200,000 kilowatts in 1957 to 20,600,000 kw.
- Dollar expenditures for this capacity will go from $\$\frac{1}{4}$-billion in '57 to almost $1.5-billion in '64.
- With the projected growth in plant capacity, 8,000 metric tons of natural uranium and 26 of U^{235} may be needed annually by 1964.
- In the next four years $300-million are expected to be spent on private nuclear research and development.
- By 1964, 30,000–40,000 professional personnel will be needed in atomic energy.

A key assumption in the study is that there will be a need in this country for 8,000–10,000 megawatts of electric capacity in the next ten years. It is also assumed that nuclear power plant costs will be reduced 50% in the next five years and another 50% in the following seven years.

The further assumption is made that "nuclear plants will be selected over conventional plants at equal costs, because nuclear power has greater potential for cost reduction after startup than conventional plants, and has the advantage of offering experience in a necessary future development."

With these assumptions and expected trends in conventional plant costs, Fig. 1 is obtained. It is apparent that in the next six years propulsion reactors will make up the largest portion of the total business. To get the growth shown, the survey assumes that 75 such reactors will have been constructed or will be under construction by 1965.

It is not expected that the first small power reactors (up to 100 Mw-heat) will be built domestically until three or four years' experience with military and foreign units. As shown in Fig. 1, such reactor construction will be 5–20% of the total.

It is anticipated that nuclear power may become economic in 1962 at a power cost of 5–7 mills per kwh, giving the sharp rise for the later years.

Capital costs for large central-station power reactors and for small reactors were assumed to follow the "halving"

Looking Ahead

In preparing its "growth survey," the Atomic Industrial Forum had to make many broad assumptions and extrapolations to fill the void left by the lack of experience data. In its report, the Forum tried to overcome this handicap by using "maximum" and "minimum" predictions. However, in this summary of the report, NUCLEONICS has used only the "maximum" data because of the greater interest in this for evaluation of market potentials.

With this qualification (and the further one that the numbers in Table 1 for small and propulsion reactors are based on very little plant experience), the Editors of NUCLEONICS feel the report provides a very useful basis for looking ahead. Copies of the full report are available at $7.50 from Atomic Industrial Forum, Inc., 260 Madison Ave., New York 16, N. Y.

TABLE 1—Projected Nuclear Component Market (millions of dollars)

Items	1955 Plants					1959 Plants					1961 Plants					1963 Plants				
	Large	*Small*	*Propul.*	*Total*	*%*	*Large*	*Small*	*Propul.*	*Total*	*%*	*Large*	*Small*	*Propul.*	*Total*	*%*	*Large*	*Small*	*Propul.*	*Total*	*%*
Building & shielding	8	7	5	20	20	12	20	60	92	18	49	23	73	144	17	178	25	85	288	19
Vessel & internals	4	4	7	15	15	7	10	80	97	19	27	13	100	140	17	107	15	120	242	16
Control apparatus	3	2	5	10	10	4	6	50	60	12	15	10	67	92	11	71	9	80	160	11
Heat exchangers	3	2	4	9	9	4	7	45	56	11	17	12	59	88	11	92	10	70	172	11
Pumps	4	3	5	12	12	5	8	65	78	15	21	8	82	111	13	71	12	104	187	12
Valves & fittings	1	1	2	4	4	2	3	15	20	4	8	4	23	35	4	39	4	27	70	5
Piping, welding & insp.	2	1	2	5	5	3	4	20	27	5	11	6	25	42	5	53	7	40	100	7
Tanks & auxil.	1	1	1	3	3	2	3	10	15	3	8	4	15	27	3	28	4	25	57	4
Instrumentation	3	2	4	9	9	3	4	15	22	4	11	6	40	57	7	28	7	70	105	7
Fuel handling	2	2	2	6	6	3	4	20	27	5	11	7	27	45	6	21	7	30	58	4
Auxiliary systems	3	2	2	7	7	3	5	15	23	4	13	7	25	45	6	21	8	35	64	4
Total	36	27	39	100	100	48	74	395	517	100	190	100	536	826	100	709	108	686	1,503	100

principle mentioned earlier, with the costs cut in half in the first five years and in half again in the following seven years. Investment in both small and propulsion reactors was said to be 2.5 times that of large plants. And the cost of propulsion units was assumed to be reduced 20% in successive four-year periods.

Figure 2 and Table 1 were derived with the use of these trend predictions against current cost figures.

In determining the fuel needs of large reactors, it was felt that in the next five years there would be the following distribution of reactor types, according to percentage of total heat output: 73%—solid-fueled thermal units, 12%—homogeneous units, and 15%—fast breeders. In the following five years, this would be the breakdown: 70%—solid thermal (mostly boiling water), 22%—homogeneous, and 8%—fast breeders. Natural and enriched uranium would be involved in these types.

The small and propulsion reactors would use highly enriched uranium.

Table 2 lists unit fuel requirements for the different groups of reactors. The values listed here, multiplied by the anticipated heat capacity additions shown in Fig. 1, give the data for Fig. 3.

Based on these charts, the survey predicts a breakdown of the annual fuel business in 1965 as follows: raw materials—$400-million; chemical reprocessing—$140-million; fuel fabrication—$200-million; and waste treatment and storage—$30-million.

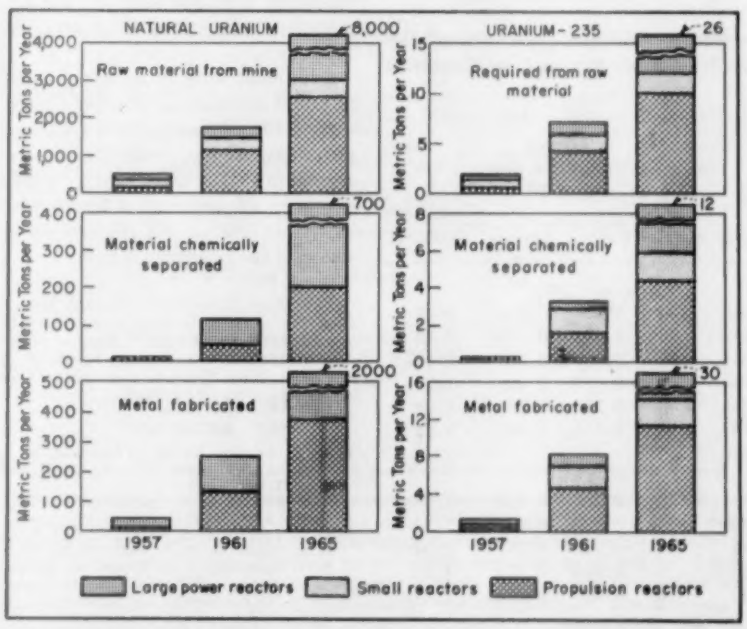

FIG. 3. Estimated fuel requirements

TABLE 2—Unit Fuel Requirements (kilograms/megawatt-heat)

	Nat., depleted U		*U-235*		*Th*
	'55–'59	*'60–'64*	*'55–'59*	*'60–'64*	*'60–'64*
Large Central Stations					
Inventory*	300	130	2	1	20
Make-up†	9	3	0.25	0.20	0.3
Recycle‡	200	35	5	0.3	2
Small Plants					
Inventory	—	—	4	2	—
Make-up	—	—	0.1	0.1	—
Recycle	—	—	0.4	0.3	—
Propulsion Plants					
Inventory	80	80	2.7	2.7	—
Make-up	1.6	1.6	0.09	0.06	—
Recycle	16	16	1	0.35	—

* Inventory, or fuel investment, including the initial loading, the pipeline tie-up for fuel, fabrication, cooling, and processing, and the inventory of materials for associated research and development activities.

† Annual make-up, including the quantities of material actually consumed in the reactor and losses resulting from fuel fabrication and processing.

‡ Annual recycle rate, or the steady-state flow through the processing plant.

CROSS SECTIONS

Effect of Free-Radical Acceptors on Radiosensitivity of *Ps. Fluorescens*

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Free-radical acceptors (FRA) have been proposed as agents for minimizing undesirable side reactions observed with sterilizing doses of ionizing radiations (*1*). When added prior to irradiation treatment, FRA's have a greater affinity for the free radicals and activated solute molecules (produced by radiations acting on the solvent) than do flavor molecules (*2, 3*).

Since certain species of microorganisms are destroyed by the indirect effect of the radiations as well as by direct hits (*4, 5*), the question has logically been raised as to whether the presence of the FRA can affect the radiation sensitivity of the microorganisms present in the food.

This article summarizes studies made with *Pseudomonas fluorescens*,* which is relatively sensitive to ionizing radiation and exhibits constant behavior under standard laboratory conditions. Two sets of FRA's were used, i.e., sodium ascorbate and a combination of disodium fumarate and monosodium glutamate.

Irradiation was accomplished with gamma rays from the MIT Dept. of Food Technology cobalt-60 source (*4*). Twenty-four-hour cultures of *Ps. fluorescens* were irradiated in nutrient broth and pea purée suspensions, the latter being used as an example of a commercial food product. Comparable runs were made in each of these media with and without FRA's.

Five-milliliter aliquots of the suspensions of the organisms were irradiated in Kimble "Neutraglas" ampoules. Standard bacteriological diluting, plating, and counting techniques were used throughout.

The data, summarized in the table, reveal a definite effect of sodium ascorbate at the 1% and 0.5% levels and of disodium fumarate (0.3%) and the combination of disodium fumarate and monosodium glutamate in nutrient broth. Similar results were obtained in pea purée suspension.

These data indicate that, in the presence of FRA's, the inactivation dose (D_0) is increased. Calculations of the isoefficiency ratio, i.e.,

$$\frac{\text{dose required to give } 10^{-1} \text{ survival in presence of agent}}{\text{dose required to give } 10^{-1} \text{ survival without agent}}$$

reveal that, for approximately equimolar concentrations, the ratio for sodium ascorbate (0.05*M*) is only approximately 1.37, whereas Burnett *et al.* (*1*) found that when *E. coli* was irradiated in the presence of sodium hydrosulfite, the isoefficiency ratio was 3.7 for sodium hydrosulfite.

The studies reported herein are of additional value in that they add further evidence to the theory that microorganisms are destroyed by ionizing radiations indirectly as well as by direct hits.

Additional work is necessary to ascertain if sporulating, anaerobic organisms, such as those used for thermal processing studies, react in a manner similar to that observed with *Ps. fluorescens* in the presence of FRA's, that is, if they exhibit an appreciable increase in the isoefficiency ratio.

* * *

This paper (Contribution No. 215, Dept. of Food Tech., MIT) is taken in part from the thesis submitted by Philip S. Rane in partial fulfillment of the requirements for the S. B. degree in Food Technology at the Massachusetts Institute of Technology.

* Two strains of *Ps. fluorescens* were used. The first, Stanier Strain 3.12, used for most of this work, was lost through a laboratory accident. The Gaughran Strain was used for the fumarate experiments.

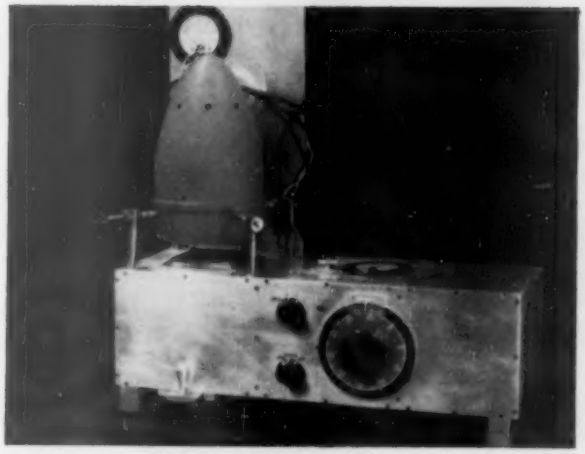
FRA Effect on Inactivation Dose of *Ps. Fluorescens* Exposed to Cobalt-60 Gamma Rays

Additive	Concentration (%)	Molality	No. of samples	Average inactivation dose ($rep \times 10^{-4}$) Control	Additive	D_0 additive / D_0 control
In nutrient broth						
Sodium ascorbate	1	0.0505	100	0.376	0.501	1.33
	0.5	0.025	36	0.381	0.473	1.24
	0.1	0.005	36	0.382	0.380	0.995
Disodium fumarate*	0.3	0.019	36	0.215	0.269	1.25
	0.1	0.006	36	0.216	0.221	1.02
Disodium fumarate + monosodium glutamate	0.3 0.5	0.019 0.03	36	0.216	0.263	1.22
In pea purée						
Sodium ascorbate	1	0.0505	6	0.220	0.305	1.38
	0.5	0.025	6	0.220	0.273	1.24
	0.1	0.005	6	0.220	0.229	1.04
Disodium fumarate	0.3	0.019	6	0.220	0.275	1.25
	0.1	0.006	6	0.220	0.223	1.01

* Culture changed before testing fumarate from Stanier Strain 3.12 to Gaughran Strain.

BIBLIOGRAPHY

1. W. T. Burnett, Jr., G. E. Stapleton, M. L. Morse, A. Hollaender, *Proc. Soc. Exptl. Biol. Med.* **77**, 636 (1951)
2. B. E. Proctor, S. A. Goldblith, NUCLEONICS **10**, No. 4, 64 (1952)
3. B. E. Proctor, S. A. Goldblith, C. J. Bates, O. A. Hammerle, *Food Technol.* **6**, 237 (1952)
4. S. A. Goldblith, B. E. Proctor, S. Davison, E. M. Oberle, C. J. Bates, B. Kan, O. A. Hammerle, B. Kusmierek, NUCLEONICS **13**, No. 1, 42 (1955)
5. G. E. Stapleton, A. Hollaender, *J. Cellular Comp. Physiol.* **39** (suppl. 1), 101 (1952)



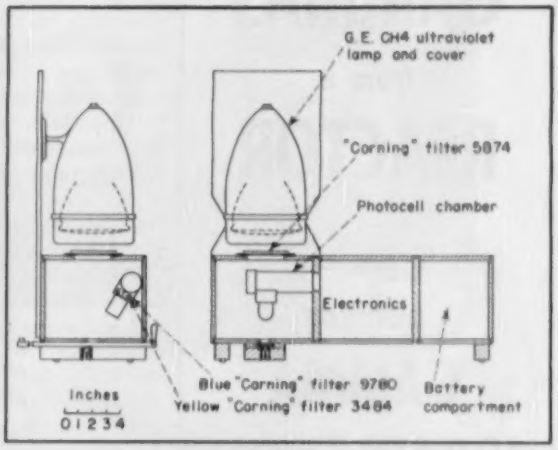


FIG. 1. Fluorophotometer photo tube and filters are installed in housing that can be adjusted so that fluorescent light from sample shines directly on tube. Tube base is removed to reduce leakage. Filters, same as those used by Neuman *et al.* (*1*), isolate fluorescence line at 5,550 Å. Four thumbscrews move ultraviolet source housing to best focusing position

A Simple D-C Fluorophotometer for Detecting Uranium

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The fluorescence of uranium under ultraviolet light (first recorded by Stokes in 1852), using a uranium salt fused with sodium fluoride, has been used recently for detecting uranium in urine. Although the instrument described here (Fig. 1) was developed for this purpose, it was anticipated that something could be learned about the factors influencing sensitivity, i.e.,

1. The effects of aging and variations of the ultraviolet light.
2. The effect of various methods of preparing the sodium fluoride buttons.
3. The sensitivity of various methods of electronic detection.

To isolate and investigate these effects would be an arduous, time-consuming task. It is the purpose of the present investigation to show that a simple workable instrument can be built with the same sensitivity as other methods, and that the practical limit of detection is not bounded by the electronic circuitry.

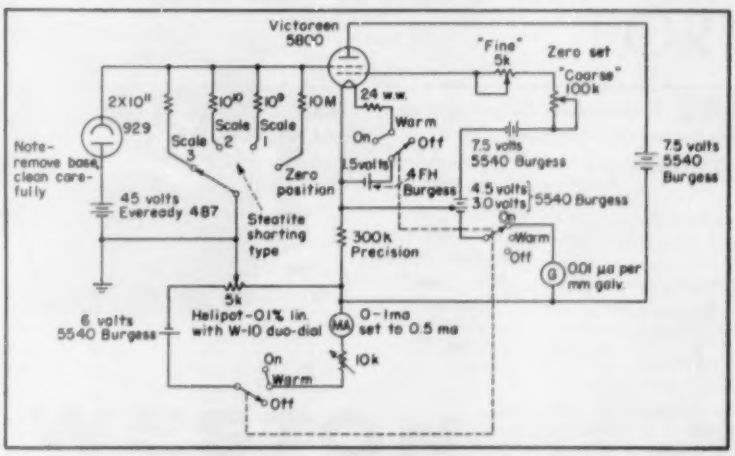

FIG. 2. Electronic circuit, providing impedance conversion rather than voltage gain, is not a cathode follower, since electrometer-tube gain is about unity. However, it is self-compensating for filament-emission changes—major source of instability in d-c amplifiers. Change across cathode resistor without galvanometer connected is ½ volt for 1-volt change on grid; with 0.01-μa/mm galvanometer in circuit, 3-mv change on grid can be observed. Advantage lies in circuit's high stability and null operation; grid is returned to original potential by 5k helipot biasing resistor; linearity is thus largely determined by linearity of helipot and voltage coefficient of high resistance in grid circuit

Circuit

To get some idea of the various effects noted, the electronic circuit must not contribute anomalies. Thus, a simple type of slide-back-voltmeter arrangement was chosen. Because of the low currents from the phototube, it was thought that the d-c technique of Neuman *et al.* (*1*) could be further improved with an electrometer tube. The circuit chosen (Fig. 2), therefore, is of a slide-back-voltmeter electrometer-tube cathode-follower type that has been used extensively in this laboratory for some years (*2*).

Procedure

In general, the procedure for preparing samples is similar to that of Neuman *et al.* (*1*) and Price, Ferretti, and Schwartz (*3*).

The platinum dishes containing the sample are flamed over an open gas-air

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burner, the flame of which is kept constant with manometers on both the gas and air lines. The 1-min fusion time starts when the last bit of sodium fluoride melts. At the start of timing, the flame is moved slightly to the side to allow the flux to spread evenly over the dish, then returned so that the dish remains over the center of the burner. A 5-min time lapse should be allowed before returning the dishes to the porcelain plate, to permit uniform freezing. If air drafts are kept at a minimum, better fusions are obtained. Too severe drafts during fusion cause the flux to turn yellow, which lowers the fluorescence. Sometimes refusion of the yellow flux clears it to the usual white crystals.

The measurement of the amount of uranium is comparative so that a standard stock solution is made, plotting grams against vernier readings. After dissolving 2.11 gm uranyl nitrate hexahydrate in one liter of 2*N* nitric acid, a series of 1-to-10 dilutions is made to obtain a final concentration of 0.01 μg uranium per milliliter of solution. Volumes of 25, 50, 75, and 100 microliters (or 20, 50, etc.) are used and the curve plotted with these points. Separate graphs have to be made for higher concentrations measured on a less sensitive scale. To check for drift, blank readings are taken between each set of unknowns and the difference averaged in the calculations. Blank spike readings provide a check on the possible contamination of blanks and also check the instrument.

In calculations, the blank readings are subtracted from those of the unknowns to give the exact vernier reading of the sample to be read on the graph. Readings from the graph are in grams per 100 microliters. Urine samples are reported in micrograms uranium per liter of urine, and air samples in total micrograms per sample.

Figure 3 is a typical calibration for the instrument on scale 2. By this procedure, over a period of 3 yr many hundreds of samples have been analyzed.

Sensitivity Factors

With this experience, it is possible to draw some general conclusions as to the nature of the instrument and the procedure.

Effects of aging and variations of u-v light source. In practice, the light source is turned on on Monday morning and turned off the following Friday afternoon. A new bulb shows an increase in intensity of approximately 10% in a period of two weeks, after which it remains at a constant intensity for several months; thereafter it gradually declines. This general behavior is independent of voltage-regulating transformers.

There are wide variations in intensity between lamps from various manufacturers, but in general they all show the same behavior.

We believe this behavior is attributable to the light source for the following reasons: It is very easy to check the sensitivity of the electronic circuit inasmuch as a given change of duodial setting should always deflect the galva-

TABLE 1—Uranium Determinations Made on NYO Samples

	Uranium concentrations (μg/liter)	
Sample no.	*Los Alamos results*	*New York Operations "true" values*
1	82	98
2	51	54
3	11	16
4	11	6
5	0	0
6	11	26
7	34	46
8	69	76
9	0	2
10	0	8
11	25	34
12	51	64

TABLE 2—Comparison of Los Alamos and NYO Instruments

	Uranium concentration (μg/liter)		
Sample no.	*Standard solution*	*Los Alamos*	*NYO*
1	10	8	13
2	10	10	14
3	10	10	11
4	10	10	11
5	10	10	8
6	10	9	12
7	100	101	99
8	100	101	91
9	100	101	99
10	100	101	105
11	100	101	96
12	100	99	91

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nometer a given number of divisions. This effect was always checked with a blank that was made from the same lot of C.P. sodium fluoride.

Effects of NaF button preparation. Experience has shown that the preparation of the sodium fluoride buttons is the most critical operation in the whole method. The buttons should crystallize as uniformly as possible to a white color; occasionally brown spots have appeared that affect the sensitivity, but the addition of 10% sodium carbonate minimizes this condition.

There are wide variations in the backgrounds of sodium fluoride, although spectrographic analysis of various samples has not shown conclusive reasons for this. At present the method consists of trying sodium fluoride from various sources and selecting the samples with the lowest background. An acceptable batch of sodium fluoride on scale 2 of this instrument gives a reading of 22–44 divisions on the duodial.

The cleaning of the platinum dishes is important because of the sensitivity. The dishes are first cleaned in concentrated sulfuric acid in a large platinum dish until all the flux dissolves, then rinsed well and boiled in 1:1 hydrochloric acid, followed by repeated rinsings and boilings in concentrated nitric acid. Clean dishes should be kept in concentrated nitric acid all the time, and before using brought to a boil and rinsed at least three times with distilled water.

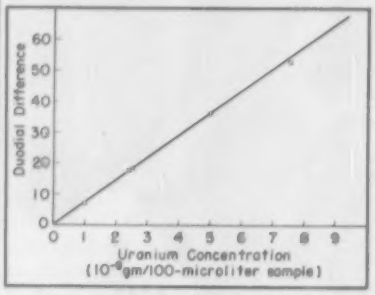


FIG. 3. Typical calibration of fluorophotometer

The fluorescence depends on the method of cooling the buttons. The best practice is to move the flame to one side rather than move the dish. Some preliminary experiments indicate that fast cooling is better than slow cooling.

Experiments indicate that fluxing and cooling in an argon atmosphere may be desirable. As a result of this process, the buttons were loose in the dish, and it was possible to turn them out.

Sensitivity of the electronic detector. Scale 3 of the present instrument is completely unusable, because the background leakage of the light source and the background of the blank sodium fluoride threw the instrument completely off scale.

With the light off and no blank, grid current is negligible. This is demonstrated by zeroing on the zero position and then switching to scale 3. Any grid current then develops a grid voltage across the 2×10^{11}-ohm resistor and disturbs the zero setting. The zero is the same on both settings so that grid current may be assumed to be negligible on this scale.

We therefore conclude that, although there is available an increased sensitivity of 20, it is unusable because of the other factors.

As a further check on the sensitivity of our instrument, in 1951 samples were exchanged between Los Alamos and the AEC New York Operations Office. These samples were spiked so that only the originating office knew how much uranium they contained.

The New York Operations instrument is different in the sense that the fluorescent signal is amplified by photomultipliers using modulating techniques.

Table 1 summarizes the values that Los Alamos found compared with the true value calculated on the basis of a weighed amount of uranium oxide by the New York Operations Office.

Los Alamos prepared 12 samples by the method previously described; 6 samples contained 10 μg/liter and 6 contained 100 μg/liter. Table 2 summarizes the values that were found on both the Los Alamos and New York instruments.

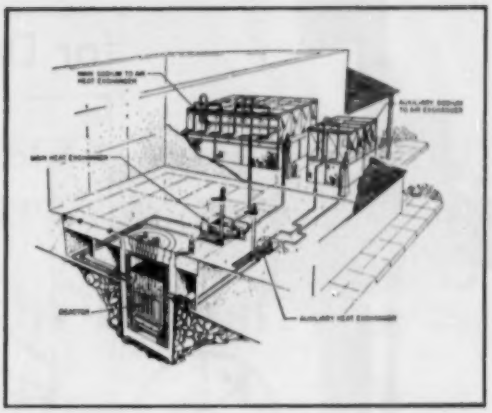
Inasmuch as it is evident that the agreement by these two totally different instruments is quite acceptable, we conclude that this simple instrument has the same sensitivity as other methods of measuring the fluorescence.

* * *

The authors wish to thank Shirley J. Riggenbach and Victoria E. Johnson for their unfailing assistance with this work. The work was done under the auspices of the U. S. Atomic Energy Commission.

BIBLIOGRAPHY

1. W. F. Neuman, R. W. Fleming, A. B. Carlson, N. Glover, *J. Biol. Chem.* **173**, 41 (1948)
2. W. C. Elmore, M. Sands, "Electronic Techniques," 1st. ed., p. 186 (McGraw-Hill Book Co., Inc., New York, 1949)
3. G. R. Price, R. J. Ferretti, S. Schwartz, *Anal. Chem.* **25**, 322 (1953)



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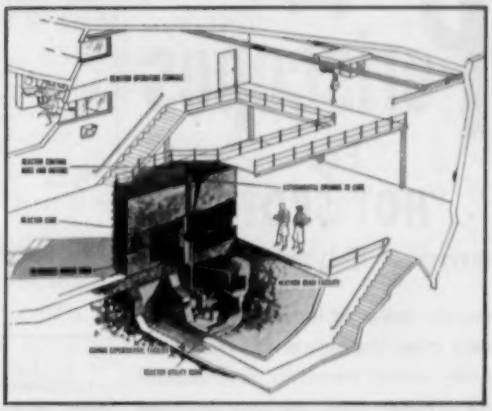

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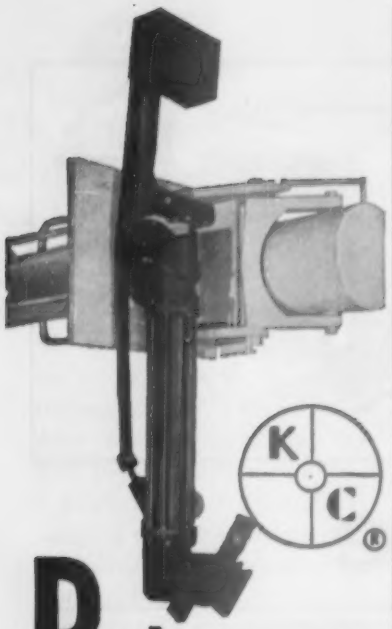

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CdS-Crystal Probes Are Convenient for Dosimetry in Body Cavities

By W. S. MOOS and F. SPONGBERG

Department of Radiology
College of Medicine, University of Illinois
Chicago, Illinois

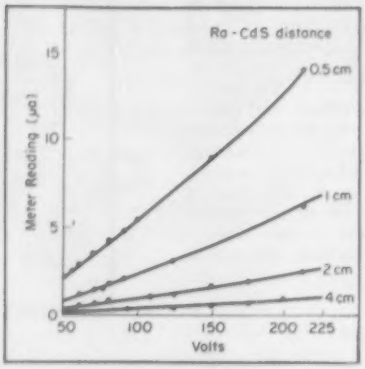

FIG. 1. Variation of CdS-crystal response with d-c potential across crystal and with 12-mg Ra needle at various distances from crystal. Minimum dark resistance of crystal is ~10^8 ohms

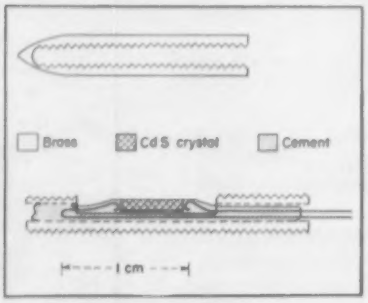

FIG. 2. Light-tight crystal assembly consists of threaded aluminum or brass tubing. Center of tubing is filed out to half its diameter; crystal is cemented here with sealing wax, providing insulation for 0.09-mm copper wire and crystal. Wire can be soldered to crystal previous to mounting (special solder compound supplied by X-Ray Dept., General Electric Co.). Projectile-shaped cover—same material as crystal support—is screwed over threaded tubing and secured with Woods metal solder; cover eliminates most softer X-ray components, and wavelength changes occurring in the absorbing object do not affect dose measurements so much

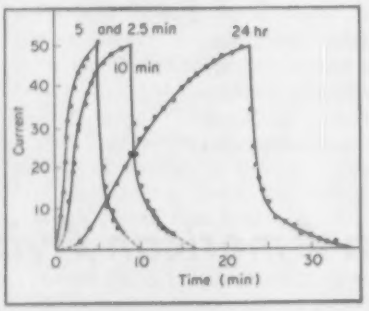

FIG. 3. Time for amplified crystal output current to reach stable value after post-irradiation periods of 2.5 min to 24 hr

Although cadmium sulfide crystals have been in use as principal elements for low-energy X-ray-beam stabilizers (*1, 2*), the smallness and economy of these crystals, together with their photoelectric properties and self-contained amplification, make them a desirable addition to radiation detection and measuring instruments.

The average size of a crystal is about 5 mm long or less and approximately 1.5 mm in diameter. The smallness of such a crystal permits its being mounted in probes of very light design. This is of particular interest for constructing probes used in medical radiology, where intracavitary radiation measurements are desired. Ionization chambers could not compete in sensitivity with such crystals at relatively low-level radiation sources, such as in radium applicators.

The radiation response of CdS crystals, which varies from crystal to crystal, is wavelength dependent (see table) and varies with the d-c potential applied across the crystal (Fig. 1). Since CdS crystals are also sensitive to visible light, they must be enclosed in light-tight chambers (Fig. 2). The chamber is small enough to be sealed to a USCI X-ray USA 10 Bard 363 urethral catheter. It is also possible to build a crystal into a larger-sized hypodermic needle, although losing flexibility in this way. This light sensitivity might eventually be of interest in the design of β-particle detectors, making use not only of the crystal reaction to the particles, but also of the scintillation characteristics of plastics and liquids.

To obtain readings at the very low dose rates frequently encountered in radium dosimetry, one can feed the signals coming from the crystal into a small d-c feedback amplifier.

One of the great disadvantages of such crystal-operated dosimeters is the long time needed to reach a stable output current during irradiation.* Fig-

* Cadmium selenide crystals have an approximately 10× faster response; however, their loss of sensitivity is about proportional.

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ure 3 shows that approximately 24 min is required to obtain the maximum reading if the crystal was not exposed to radiation for 24 hr or longer. After shorter rest intervals, the maximum current is reached earlier. After intervals of 2.5–5 min, the fastest response to maximum reading is obtained, which is about 1 min. Restoration of zero current after removing the radiation source is little affected by time. Becker *et al.* (*3*) reduced the response time of their instrument by placing it near a radium source while not in use. We modified this idea by placing some C^{14} right next to the crystal (0.1 μc) inside the shell. This had some effect, but not significantly, probably due to insufficient amounts of C^{14}. The input resistance of our amplifier was variable in increments of 10 with the highest sensitivity at 10^7 ohms.

Although all measurements are reproducible and accurate, each crystal assembly needs its own calibration chart. A typical chart is shown in Fig. 4. The angular response distribution of a brass probe chamber is shown in Fig. 5.

Preliminary results obtained from phantoms and two patients indicate good agreement with the expected results. Further investigations and improvements are contemplated. A possibility is that the registration of pulses produced in the crystal by γ- as well as β-radiations might permit faster dose analysis than d-c amplification.†

* * *

The authors are very indebted to Dr. Jacobs of the X-Ray Dept., General Electric Co., who gave very valuable advice and supplied the CdS crystals and special solder.

Wavelength Dependence of CdS*

KV_p	HVL	μa per r/min
50	1.6 mm Al	1.0
100	0.75 mm Cu	8.0
250	4.5 mm Cu	6.0
Ra		1.6†

* Applied d-c potential is 100 volts.
† Own measurements; the rest of the data was supplied to us by the General Electric X-ray Dept.

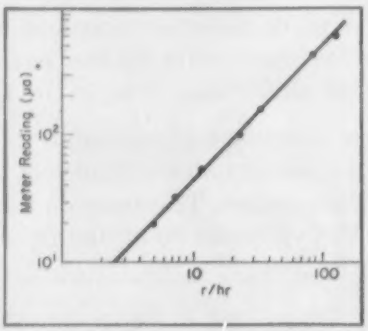

FIG. 4. Typical crystal calibration

BIBLIOGRAPHY

1. J. E. Jacobs, *Elec. Eng.* **70**, 667 (1951); *Electronics* **24**, No. 8, 125 (1951)
2. J. F. Howell, *Proc. Natl. Electronics Conf.* **8**, 121 (1953)
3. J. Becker, K. E. Scheer, A. Kubler, *Strahlentherapie* **88**, 34 (1952)

† CdS crystals seem to be efficient for such techniques. They yield approximately 1-mv pulses for 1,000 volts/cm with a 10^{-6}-sec pulse rise time and 10^{-5}-sec duration. Personal communications by T. Fields, Assistant Director, Radioisotope Unit, Hines Veterans Administration Hospital, Hines, Ill.

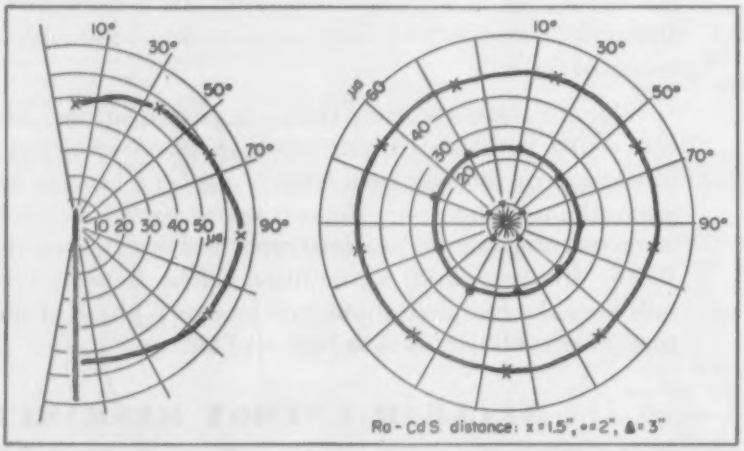

FIG. 5. Angular dose-rate response of crystal. At left, distribution in axis plane of crystal chamber with 10-mg Ra needle at points equidistant from crystal; maximum directional deviation of output current is 20% of maximum reading. At right, distribution with axis of probe at center and 12-mg needle placed in concentrically located holes drilled in Lucite; maximum angular deviation is <5%. In both cases, amplifier input resistance was 10^7 ohms

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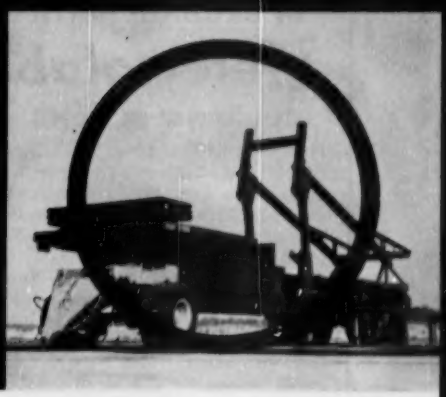

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Tracer doses of NaI^{131} for thyroid-uptake studies can be measured out conveniently by utilizing the principle of the constant-flow buret,† which permits dispensing known volumes of liquid from a reservoir by controlling the duration of flow rather than by observing buret or pipet markings. Thus, with mechanical control, excessive radiation exposure can be avoided. A large batch of diluted radioisotope can be made up, calibrated once, and used over a period of several half-lives. This technique could also probably be adapted readily to similar needs.

The equipment (see Figs. 1 and 2) is readily assembled and requires no great skill or special machinery.

The solenoid is operated by an electric timer clock (General Electric model 3TA48AA1), which can be set for a specific time period and requires only one push of a button to reset the clock, turn on the solenoid, and turn it off. Less conveniently but more economically, an ordinary hand-operated electric switch can be used in conjunction with a stop watch, or the solenoid can be eliminated and the plunger pulled by hand.

Operation

The first time the apparatus is used, it is filled with about 200 ml of water, via *B*; then the solenoid is energized to ensure removal of air bubbles in the outlet tube. Several millicuries of iodide are then added and the funnel washed down with another 200 ml of water. After the pinchclamp on *B* is closed, the solution is mixed by sucking air through *C*, using 10–15 outward strokes of the syringe plunger, or some other vacuum source.

Since the volumes of water and radioiodide solution added to the reservoir bottle are not accurately controlled, it is necessary to calibrate the solution each time the bottle is refilled. There is no need to drain the bottle before

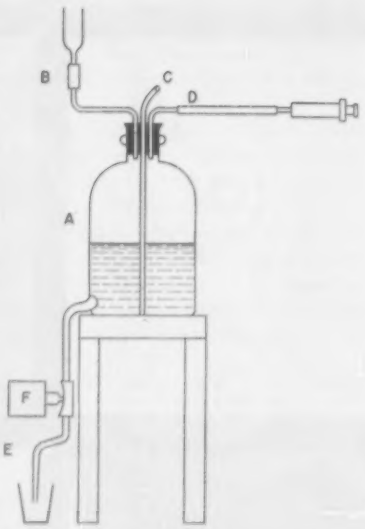

FIG. 1. Dispensing apparatus consists of: (*A*) 500-ml Pyrex aspirator bottle; (*B*) addition funnel fitted with pinch clamp and rubber tube; (*C*) glass tube drawn out to fine capillary at bottom; (*D*) short tube connected by rubber tubing to greased syringe of 10 or more ml; 5-mm-o.d. glass tube sealed to bottom outlet of bottle, which is connected by 3-cm-long rubber tube to (*E*) 5-mm tube having drawn-out tip; (*F*) solenoid operated on 110 volts, a-c, bolted on 2 × 4 board; bottle and lead shielding are mounted on 2 × 4's

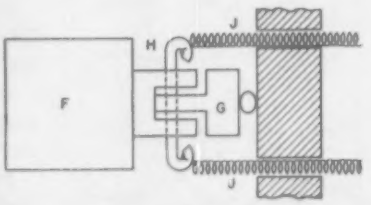

FIG. 2. Flow controller is solid-frame solenoid, continuous-duty type, with ½-in. stroke and 14-oz pull (catalog No. M8W, McMaster-Carr Supply Co.); metal bar (*G*) is inserted into solenoid-plunger slot; hole is drilled in plunger and bar and metal rod (*H*) inserted and ends bent, permitting connection with springs (*J*); *G* presses against rubber tube to shut off flow. Springs are stretched sufficiently to prevent leakage but not so much that solenoid cannot pull plunger away from rubber tube. Power failure cannot cause solution loss

* The work was done with the technical assistance of Gustav Barnes.

† J. K. Taylor, E. Escudero-Molins, *Anal. Chem.* **21**, 1576 (1949).

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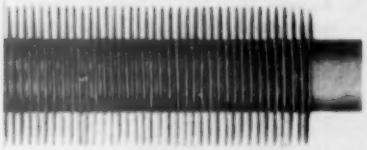
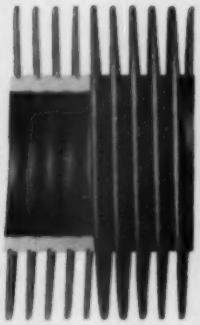


3K6—Helically finned tubing for use in lightweight airborne equipment where the fluid outside the tubes has a cross-flow for metal temperatures up to 1600° F.



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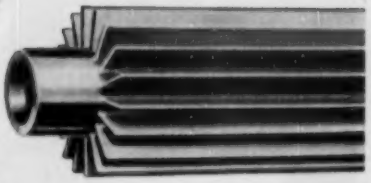

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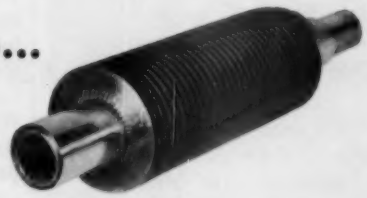

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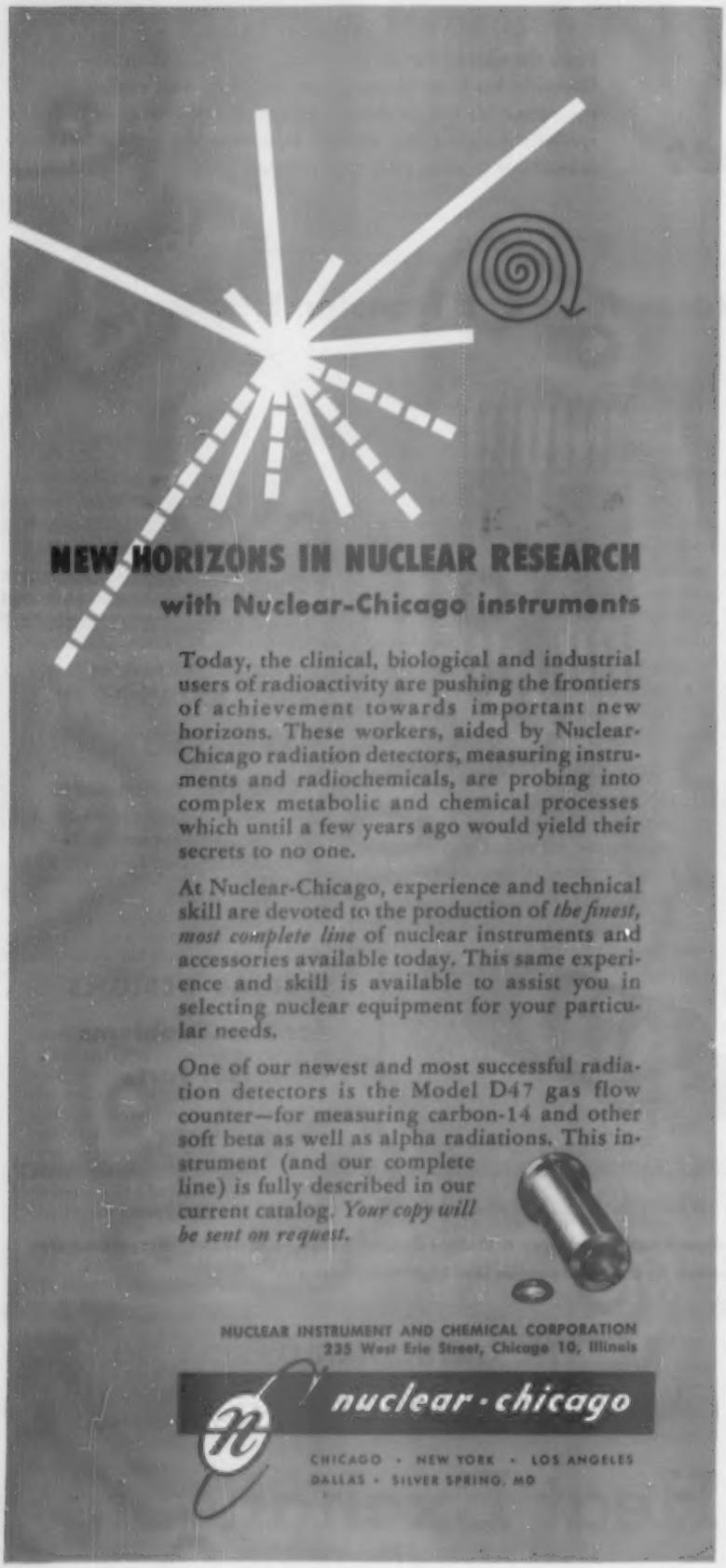
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refilling, since the residual activity is relatively low. However, the first 7–8 ml must be discarded because of the residual low-activity solution in the outlet tube.

To dispense the solution, the syringe plunger is pulled slightly until some bubbles come out of the capillary *C*. The solenoid is now actuated by the timer clock and the dose collected in a wax-paper cup for ingestion by the patient. It is important that the initial slight vacuum be present; if any length of time elapses between successive doses, the plunger should be pulled again until bubbles issue.

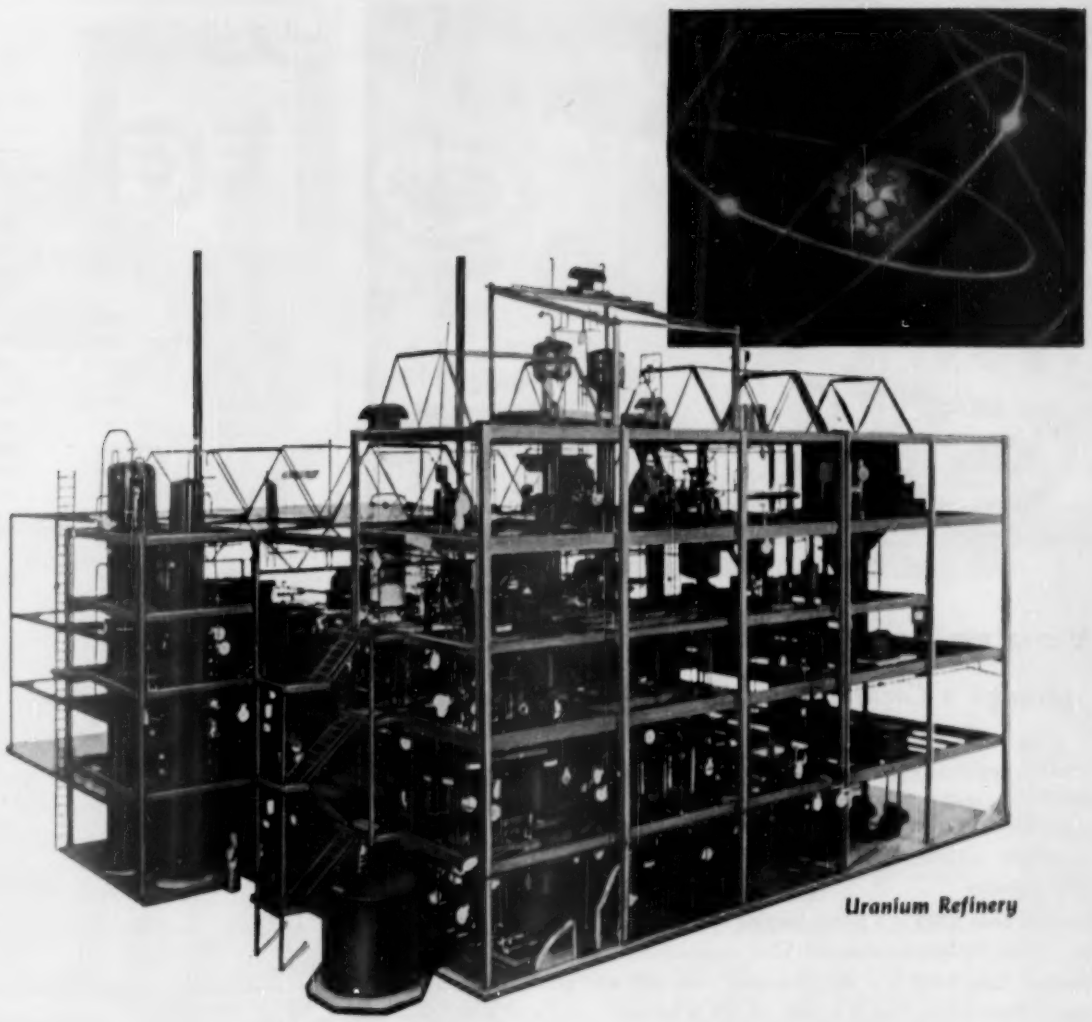
The liquid flow rate is independent of the amount of liquid in the bottle and depends primarily on the vertical distance between the tips of tubes *C* and *E*, as well as the flow resistance of the constricted tip of *E*. The solution temperature is also a factor, since the viscosity is affected; we found only a slight effect, the flow rate increasing about 2% with a 6° C rise. To reduce the importance of temperature corrections, we have kept the dispenser in an area of minimum temperature fluctuation.

Lead shielding is readily placed around the reservoir bottle, and, if desired, around the wax-paper cup and the thin tubing coming from the bottle. In fabricating the metal bar, *G*, the edge touching the rubber tube should not be too sharp and it should be parallel to the wooden board on the other side of the rubber tube. When the apparatus is not in use, the syringe should be disconnected to avoid pushing liquid up tube *C*.

Before filling the dispenser with radioactive liquid, a suitable dispensing tip must be chosen to give the desired flow rate. This is easily done by dispensing into a graduated test tube or cylinder. It is not important to know the flow rate accurately since the radioactivity per second must be determined each time the bottle is refilled. However, it is wise to check the performance of a new timer clock at various time settings, most accurately by weighing the samples delivered.

Results

Test data for our apparatus are shown in the table. On any given day, the standard deviation in flow rate is 1.2% or less, the variability decreasing with increased dispensing time. This is probably due to variations in the clock action. The maximum deviation from the mean is 2.7% of the average



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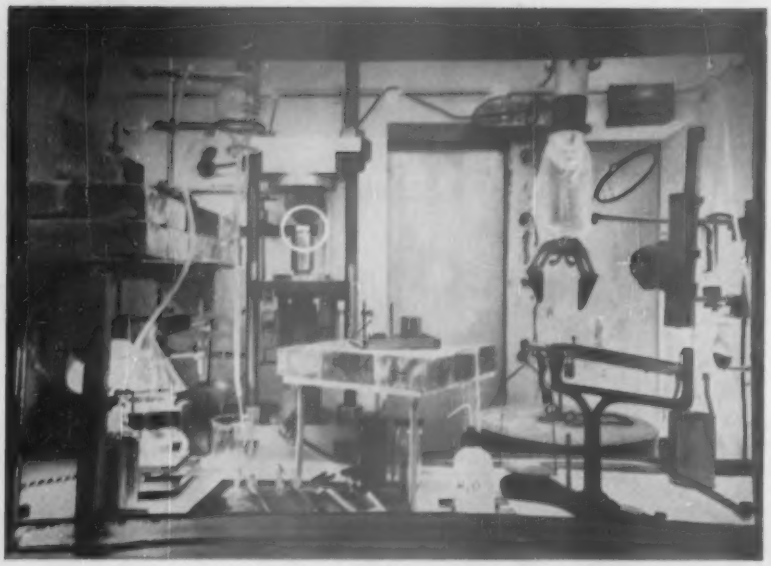
Test Using NaI^{131} Solution

Dispensing time (sec)	*Sample weight (gm)*	*Flow rate (gm/sec)*	*Activity per second* (cpm/sec)*
10	2.53	0.253	906.0
	2.58	0.258	905.4
	2.59	0.259	891.8
	2.56	0.256	909.8
	2.62	0.262	885.2
		Aver. 0.258	Aver. 899.6
		S.D. 0.0030	S.D. 9.4
25	4.44	0.261	883.7
	4.43	0.261	897.5
	4.41	0.259	892.4
	4.39	0.258	888.8
	4.43	0.261	882.3
		Aver. 0.260	Aver. 888.9
		S.D. 0.0012	S.D. 5.6
40	10.63	0.266	943.9
	10.39	0.260	909.4
	10.53	0.263	902.4
	10.46	0.262	936.8
	10.49	0.262	905.0
		Aver. 0.263	Aver. 919.5
		S.D. 0.0020	S.D. 17.3
75	19.05	0.254	868.3
	19.15	0.255	890.2
	19.18	0.256	900.4
	19.19	0.256	885.7
	19.12	0.255	897.4
		Aver. 0.255	Aver. 888.4
		S.D. 0.0002	S.D. 11.3

* Corrected for background, counter-efficiency fluctuation, and radioactive decay.

flow rate, while the standard deviation is 1.3% of the mean. The variations from day to day seem to be due in part to temperature differences.

In the test run with radioactive sodium iodide solution, the doses were collected in 30-ml serum bottles, which were diluted to the neck, stoppered, shaken, and counted with a crystal scintillation counter. It is our practice to count high-activity samples by covering the counter well with a lead cup that accurately positions the bottle and reduces the counter efficiency to a practical level. Due to variations in the geometry of the bottles, slight counting errors are obtained. This, and the intrinsic counting error, result in the higher standard deviation, 1.7% of the mean for the entire series. The maximum deviation in activity is 5.0% of the mean. This variability can be reduced by calibrating the bottles and correcting the readings.



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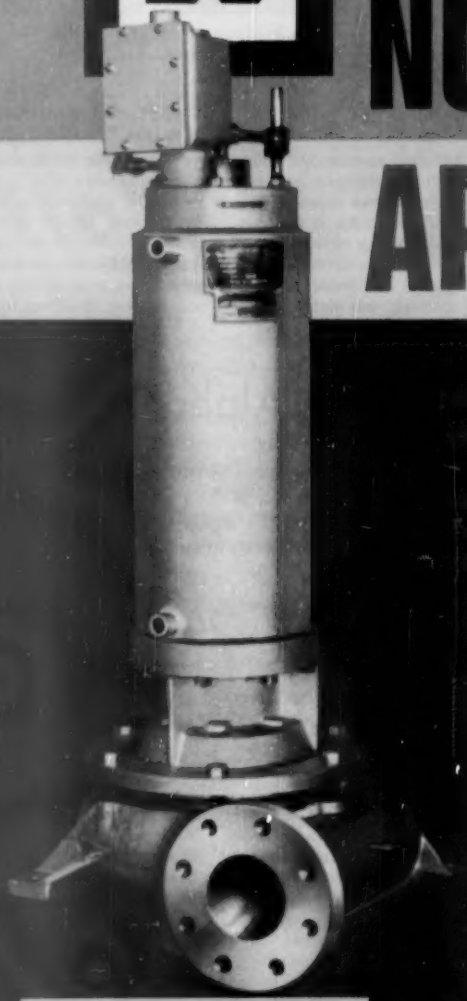

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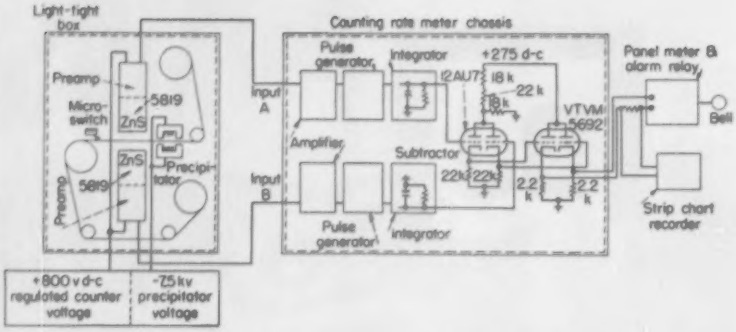

FIG. 1. Two air samples from different sources are pulled through machine by blower; dust is removed by dual electrostatic precipitator and collected on each side of 1½ × 0.003-in. moving aluminum tape. Tape then moves between two 5819 photomultipliers with ZnS screens; alpha activity on both sides is counted. Signals pass through dual-channel counting-rate meter and subtracting circuit; difference voltage output from subtracting circuit is passed through vacuum tube voltmeter to strip-chart recorder and audible alarm system. If one sample intake is in monitored enclosure and other near source of clean or normal air, differential counting-rate meter subtracts background, avoiding wait for short-lived Rn-Tn count to die out

Monitor for Airborne Alpha Particles

By D. J. KNOWLES
Instrumentation and Controls Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

To help cope with the radioparticulate problem, a monitor for airborne alpha particles has been developed at ORNL and is described here.

Design Considerations

The specifications for the model Q-1263 airborne-alpha monitor were a compromise between convenience to the user, physical dimensions, and response time. Figure 1 shows the overall plan of construction.

The precipitator (Fig. 2) concentrates the dust from a large volume of air to get the counting rate up to a reasonable value. Precipitation was chosen for concentration over filter paper or a greased plate since an inexpensive aluminum tape can be used for the collector without the possibility of self-absorption as in the filter paper; and collection of the important submicron sizes is quite good (*5*). Furthermore, approximately a month's supply (continuous operation) of tape can be put into the machine. The tape is discarded after one use since cleaning the tape for reuse would be too elaborate to be economical (*6*). Thinner tape was tried, but tore easily and tended to flutter in the air stream. The tape used is thick enough to screen high-energy alpha particles on one side of the tape from the other side. A test of the precipitator showing precipitator efficiency for various air flows using an oil smoke is shown in Fig. 3.

For the alpha detectors, flat glass plates were attached to the rounded

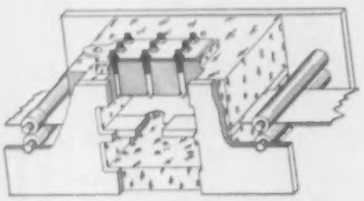

FIG. 2. Precipitator chamber is fluorothene plastic. Tape separates two air samples until after precipitation; air streams enter at back of box and flow toward front, merging as they leave front. Blower exhausts air to atmosphere through muffler. While adherence of dust on tape is excellent, very heavy deposit would come off on exit guide rollers; therefore, exit rollers have dropped center portion so that they bear on edge of tape. Precipitator uses point-to-plane geometry (*5*). Grinding burrs with ⅛-in. ball heads are used for points; sharp edges provide good ionization pattern. Nine points, ½ in. apart, cover 1½ × 1½ in. area, approximating active area of multiplier. Air piping was designed originally to move air as close to streamline flow as possible—ball points were pulled up out of air stream to avoid eddys. Testing with oil smoke showed better efficiency with ball points down in air stream; tips of points were lowered to point 3/16 in. above tape. Cross section of air streams is 1½ × 1 1/32 in. Additional efficiency and higher sensitivity could be obtained if preionization region were added to air stream ahead of precipitator. Tape moves 4 in. from center of precipitator to center of detectors at 1 ft/hr; time lag between collection and alarm is 15–20 min

The Problem

The importance of air monitoring is indicated by recent evidence (3) that airborne contamination is a more important factor in determining the health hazard than surface contamination.

Large inspired particles (10–20 microns) are rejected by expiration or by the ciliary process, although they may be swallowed with the throat phlegm. Since smaller particles (2-micron diameter and less) are more likely to reach the extremities of the respiratory system and be retained in the alveoli (1, 2), they present a greater hazard.

The initial hazard is damage to the lung tissue. If the particles are eliminated by phagocytes, they are carried to the lymph nodes, into the blood stream and to the kidneys and bone marrow.

Although beta emitters are more of a lung hazard than alpha emitters, our interest in uranium and plutonium monitoring dictated the utilization of alpha-particle scintillation detectors. The tolerance for uranium is 3×10^{-11} μc per cm³ of air and for plutonium, 2×10^{-13} μc per cm³. These tolerances take into account the radiation half-lives and the effective half-lives in the body (300 days for uranium and 43,000 days for plutonium).

Two air-monitor design requirements are therefore apparent: (1) The monitor must not discriminate against extremely small sizes of particles. (2) It must be capable of detecting extremely small amounts of activity.

Also to be considered is the alpha background (4). Small quantities of Rn^{222} and Tn^{220} and their daughters are present in the air; the controlling daughters are RaB (26.8-min half-life) for radon and ThC or C′ (10.6-hr half-life) for thoron. Thus, although the alpha background is the same order of magnitude as the contamination monitored, measuring the sample 4 and 28 hr after collection permits radon to decay over several half-lives; the amount of contamination can be found by calculation, using the ThC decay constant.

ends of the 5819 photomultipliers with Gelva resin, which is quite transparent. A silver-activated zinc sulfide screen was then applied to the flat end with thinned rubber cement (7). The ends of the 5819 tubes are within ⅛ in. of the moving tape. Testing with a known alpha source has shown the counting efficiency, including the geometry, to be 38%.

The counting-rate meter is quite

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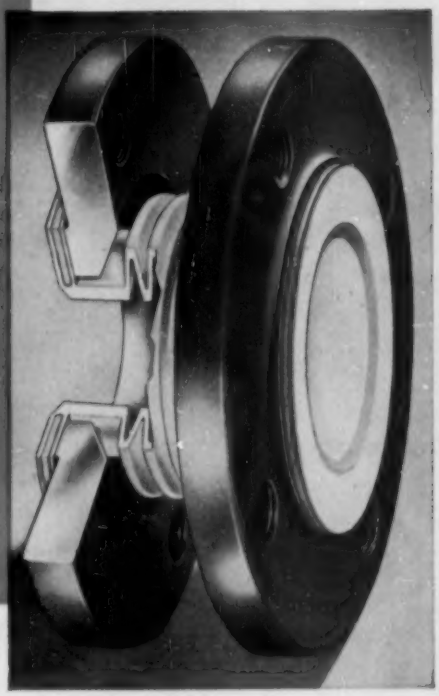

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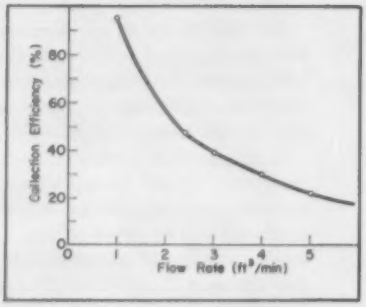


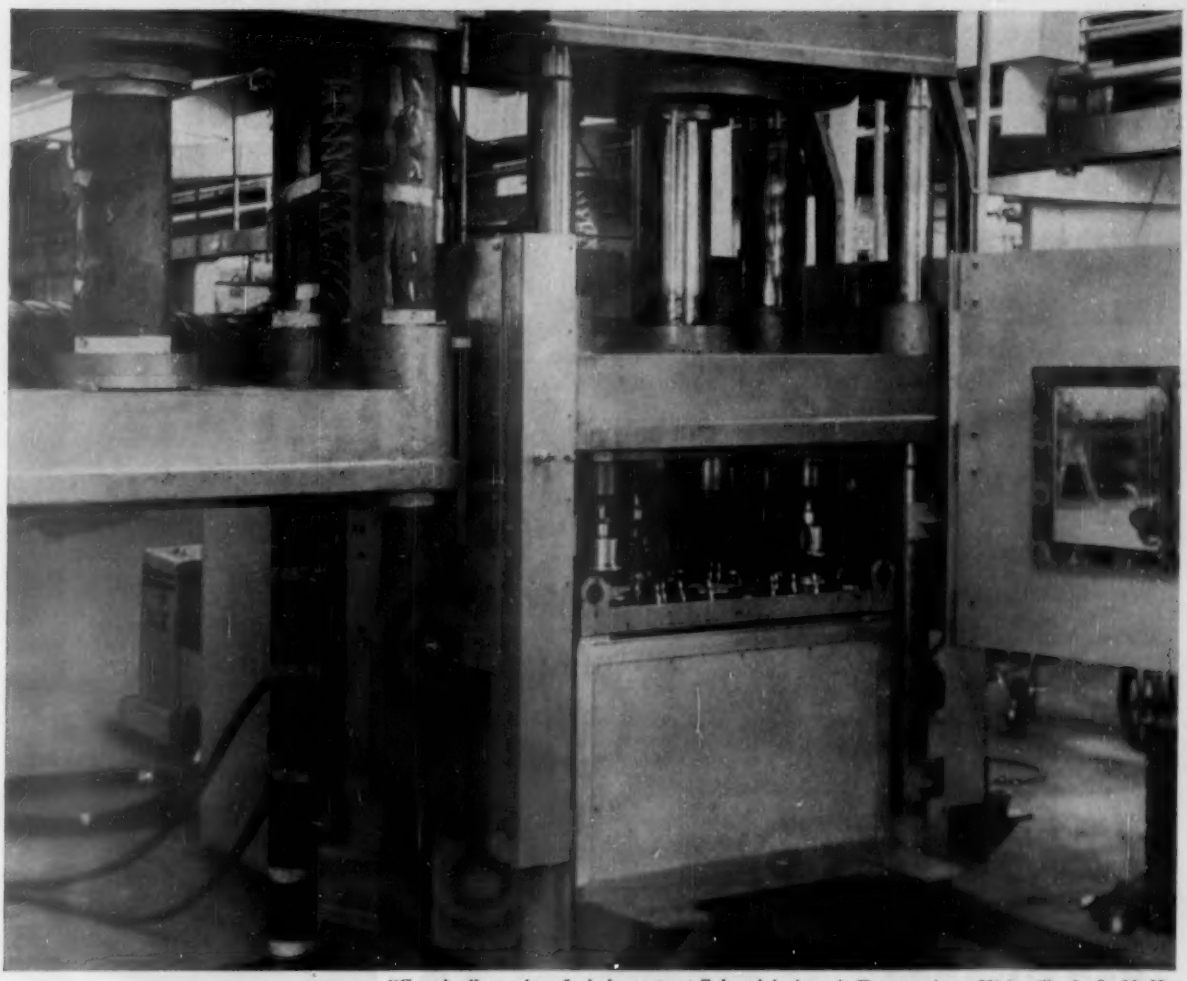
FIG. 3. Collection of precipitator with dioctyl phthalate aerosol (0.3 micron radius) and 8.25 kv from points to tape. In normal operation, 3.6 ft³ of air are drawn through each channel per minute with 34% precipitation efficiency. However, amount of material collected does not vary greatly with changes in flow if product of efficiency and ft³/min is considered

standard circuit-wise. Each channel consists of a cathode-follower preamplifier next to the photomultiplier and connected by coaxial cable to the main chassis. The two channels are still separate at this point and consist of one stage of amplification, trigger pairs that generate square pulses of uniform characteristics for each input pulse, a pump circuit to pass the square pulses to a polystyrene-insulated integrating condenser with a high-resistance bleeder, across which is measured a voltage proportional to the input counting rate.

The difference of the two rates being the quantity desired, the subtracting circuit obtains this information. The voltages from the two independent channels are applied to the grids of a dual-section tube with independent cathode resistors. The cathode voltages of this tube are now proportional to the counting rates of the two channels; reading the difference between the two with a vacuum-tube voltmeter allows the calibration of the voltmeter in terms of the differential counting rate.

Three ranges have been put into the counting-rate meter. These are 0–100, 0–200, and 0–400 cpm. Fractional probable error is less than 1%, though at tolerance (9.5 cpm) the variation on the recorder is quite large. Larger damping would be desirable except that the addition of larger integrating condensers of good quality takes up a large space and, further, increases the response time of the counting-rate circuits.

The counting rate at background swings both positive and negative. For this reason, the zero point is set at



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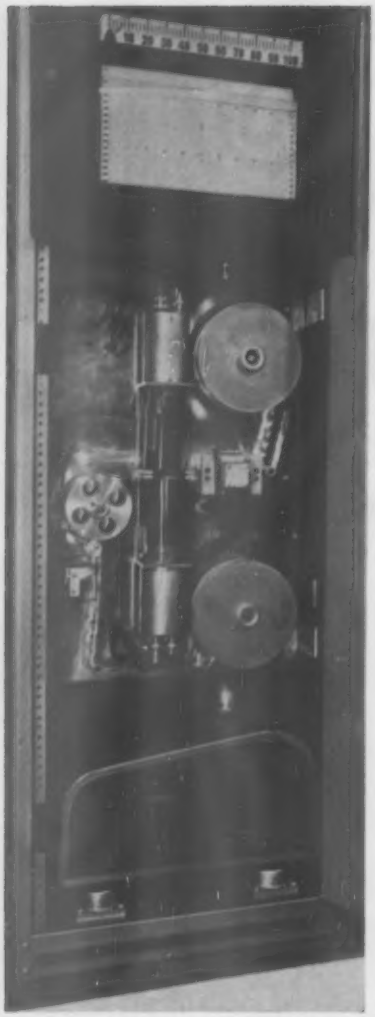


FIG. 4. Air- and light-tight box contains tape-drive mechanism, precipitator, and photomultipliers to prevent air leakage into air streams and consequent loss of accuracy. Box, blower, two power supplies, counting-rate meter, and strip-chart recorder are mounted as self-contained unit in relay rack on wheels

30 divisions on the 100-division scale of the recorder; 70% of full scale represents 7.35 times the uranium tolerance on the 100-cpm scale. The counting rate may swing 6–8 cpm positive or negative on background, making readings at tolerance and below uncertain; however, twice tolerance and above is easily discernable at a glance.

An over-all test to check operation is possible with prepared alpha sources on thin steel plates. A small door on the front of the light-tight box can be opened and one or two known sources inserted in holders in front of the ZnS screens. When operation is resumed, the sources provide known counting

rates to each channel and trouble in any section can be quickly localized by process of elimination.

Figure 4 shows the internal arrangement of parts, except that the photomultiplier tubes and the precipitator have additional electrostatic shielding in the form of small metal boxes that fit over them.

A meter-movement relay with an adjustable upper-limit set point doubles as a panel meter and alarm relay that operates a bell in case of a rise in activity to the set level. (This relay was installed after the photographs were made.) A microswitch on the aluminum tape also rings the bell if the tape should break or run out.

A second model of Q-1263, Q-1541, has recently been put into service. The differences in the two instruments are as follows:

1. The tape drive in Q-1541 is intermittent rather than continuous. Sensitivity is thus increased, since if a 15-min sample is taken, all of the material is deposited on one spot 1½ in. long, which then is moved under the detector to be counted; the activity is twice as high than if the sample had been spread over 3 in. of tape.

2. A light shutter used between the precipitator and the photomultipliers prevents light from arcs, which occasionally occur in the precipitator, from reaching the photomultiplier.

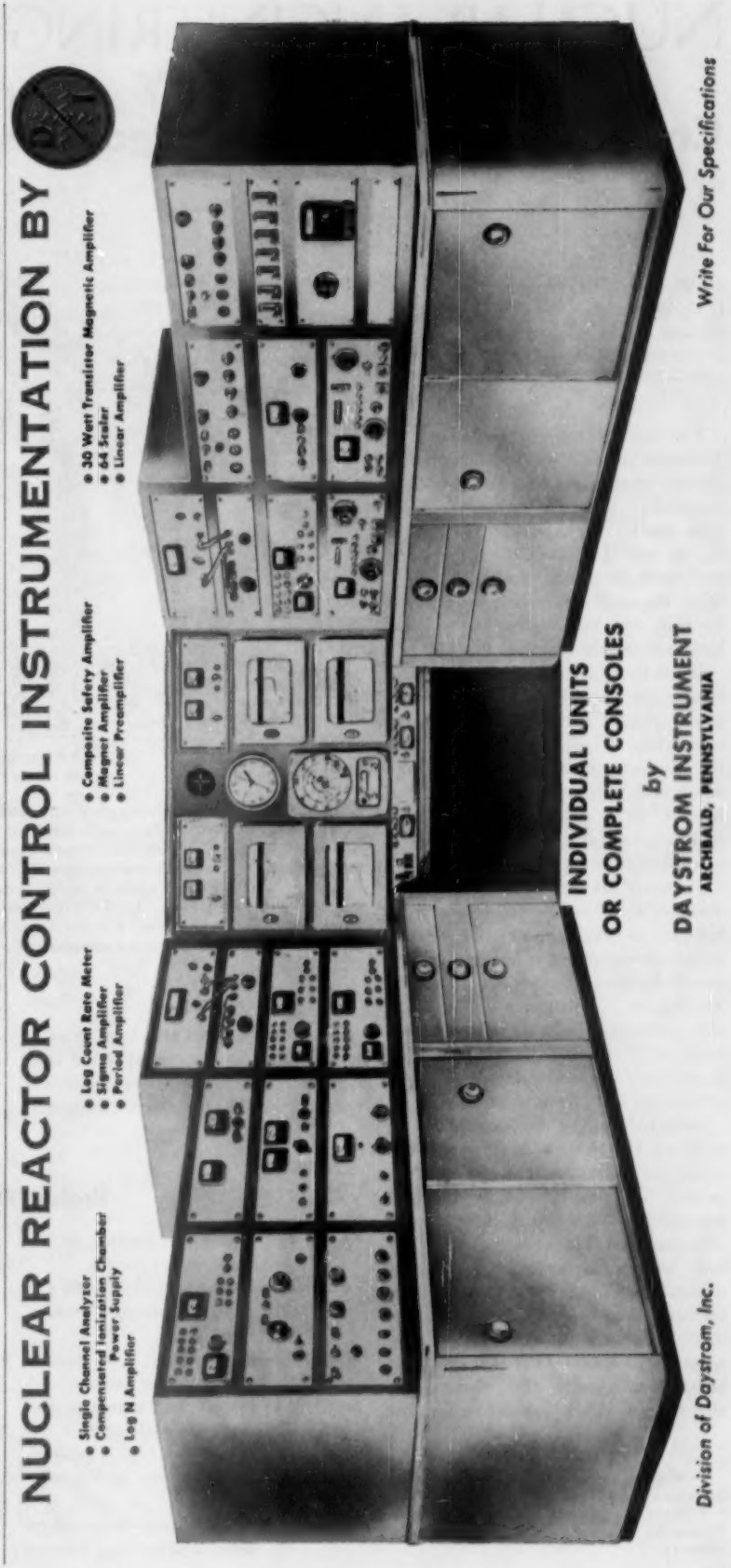
Experience with the two machines to date is limited other than for the use of the prepared samples. No large rises in airborne activity have occurred at the points where the machines are located since their installation. This is known since air monitors of other types are in use at these locations. However, the machines have given good service as long as routine maintenance has been followed.

• • •

The mechanical system was designed in its entirety by Mr. H. J. Stripling, Jr. and Mr. Joseph Weidley. Mr. T. H. J. Burnett of ORNL Health Physics Division supplied much of the background information and Mr. Louis Bradshaw of the same Division did all of the calibration with oil smoke. All of these contributions are gratefully acknowledged.

BIBLIOGRAPHY

1. T. J. Burnett, ORNL-52-11-1 (1952)
2. J. Brown, E. Cook, F. Ney, F. Hatch, *Am. J. Public Health* **40**, 450 (1950)
3. M. Eisenbud, H. Blatz, E. Barry, NUCLEONICS **12**, No. 8, 12 (1954)
4. M. Wilkening, NUCLEONICS **10**, No. 6, 36 (1952)
5. KAPL-492 (1951)
6. G. Cain, T. Burnett, private communication
7. G. Driver, P. Eisenacher, HW-30601 (1954)
8. C. Pleasance, T. Cartmell, J. Gifford, HW-26503 (1954)
9. B. Saunders, ORNL-1656 (1954)
10. C. Rainey, UCRL-1391 (1951)



NUCLEAR ENGINEERING

Cost Data on the U. of Michigan Research Reactor*

By W. K. LUCKOW and
L. C. WIDDOES†
Phoenix Project
University of Michigan
Ann Arbor, Michigan

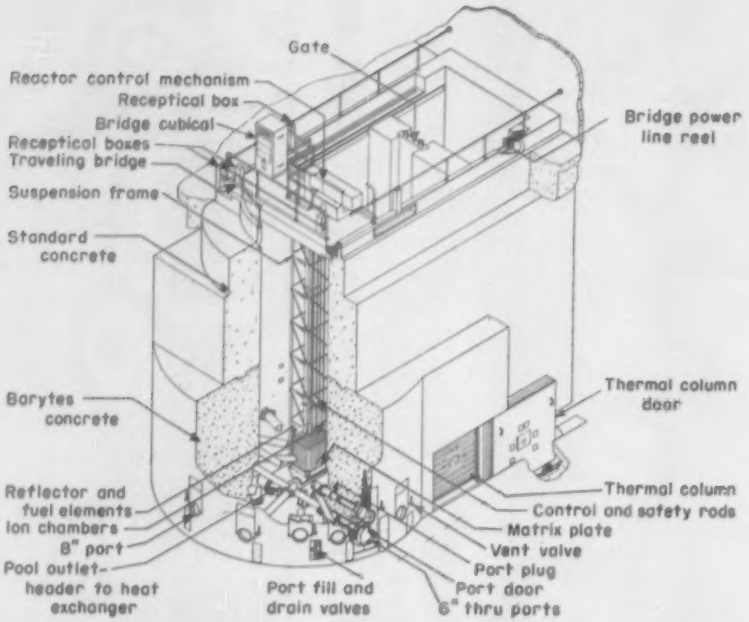
The facility for the University of Michigan research reactor consists of a 268,000-ft³ reinforced-concrete building containing a 1-Mw swimming-pool-type reactor, as shown in the figure. As the table indicates, the project has cost $989,385 as of February, 1955. With the additional estimated $[illegible],000 for staff costs to complete the project, total cost will be about $1,061,385.

When the reactor project was started it was not possible to purchase a research reactor for a reasonable lump-sum price. Thus, it was decided that the Michigan Memorial Phoenix Project would contract for design of the reactor, which subsequently would be fabricated and installed on the basis of lump-sum bids.

Design of the reactor and its building was monitored for the University by a full-time project engineer and two part-time engineers, all of whom were graduates of the Oak Ridge School of Reactor Technology. This group also handled the reactor safeguards negotiations with AEC. Extensive assistance in many areas was received from members of the University faculty and staff.

Included in the staff costs in the table are $7,155 spent in preparing the major safeguards report and $7,492 expended for other hazards studies and negotiations with the Atomic Energy Commission. This reactor was the first high-power swimming-pool-type research reactor proposed without an exclusion area other than the building itself. Less time and expense should be required to obtain AEC permission to build and operate this unit under the Commission's present safeguard policies applying to this type reactor.

The building is so constructed that if gaseous radioactive contamination is released inside, less than 10% will escape each 24 hr thereafter, provided that atmospheric conditions are normal. Office and control-room space occupy 970 ft² in the building while



REACTOR is of basic swimming-pool type modified for forced-circulation and heat-removal equipment so as to operate continuously at 1 Mw. Twelve beam holes (ten 6-in. diam. and two 8-in. diam.) are spaced around three sides of core. A 6 × 6 × 8-ft graphite thermal column is activated when core is moved about 8 ft from beam-hole position. Pneumatic tubes are provided in which samples originating at seven stations can be irradiated and returned. Auxiliary equipment includes a transfer coffin for handling beam-hole experiments, and a coffin for shipping spent fuel. Ample storage space is provided for cooling irradiated samples before examination or testing

Project Progress

Spring '52—University decides to acquire reactor facility.

June '52—Propose project to the Atomic Energy Commission.

May '53—Ford Motor Co. donates $1-million for facility.

Sept. '53—Project staff organizes and starts full-scale effort.

Dec. '53—Report to AEC's advisory committee on reactor safeguards.

March '54—Start detailed design of reactor and building;† award contract for reactor control instrumentation package.‡*

Dec. '54—Receive approval from AEC with operating instructions.

*March '55—Open sealed bids on construction of building§ and fabrication and installation of reactor.**

Feb. '56—Reactor scheduled to go critical.

---

* Officially known as "The University of Michigan Ford Nuclear Reactor."

† PRESENT ADDRESS: Atomic Project, Monsanto Chemical Company, St. Louis, Missouri.

* Babcock & Wilcox Co., Akron, O. † Smith, Hinchman and Grylls, Inc., Detroit, Mich. ‡ Leeds & Northrup Co., Philadelphia, Pa. § Jeffress-Dyer, Inc., Ann Arbor, Mich.

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RE: Our unique organization in the atomic energy field.

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laboratory space occupies 1,000 ft². Operating areas surrounding the reactor cover an additional 5,300 ft². A 10-ton crane is provided to handle heavy equipment in and out of the pool and from floor to floor.

The $1.5-million Phoenix Memorial Laboratory adjoins the reactor building. It complements the reactor facility by providing extensive equipment for experimental work. A cave in this building has remote handling equipment capable of handling 10,000 curies of Co^{60}.

In interpreting the costs, consideration should be given to the fact that no overhead was paid on any staff costs. Also, the building is being built in a location where electric power, gas, water, steam heat, roads, and other facilities are already available. On the other hand, the reactor building costs somewhat more than a strictly functional building because it conforms to the over-all architectural plan for the north campus of the University of Michigan.

Cost of the Reactor Project

Item	*Cost ($)*
Project staff costs	**~46,679**
Technical salaries (as of 2/55)	20,885
Travel (as of 2/55)	3,447
Supplies, phone, secretary's salary, and miscellaneous expenses (as of 2/55)	10,347
Estimated staff costs, 2/55 to 2/56	~12,000
Design costs	**46,523**
Building	36,911
Reactor and auxiliaries	9,612
Construction costs*	**774,183**
Building (base price)	506,970
Air dryer	10,500
	517,470
Reactor (base price, including thermal column)	141,400
Fast pneumatic system	22,600
Shipping coffin	10,605
Transfer coffin	12,895
System instrumentation	43,894
Cooling tower	9,830
Water purification	8,489
Pool lining†	7,000
	256,713
Miscellaneous costs	**134,000**
Site improvements	30,000
Construction supervision by U. of Mich. supervising architect	4,000
Hot cave in adjoining building	100,000

* The $527,300 bid reported in NU, March '55, p. 11, for the building includes the air dryer and cooling tower; the $164,000 figure reported there for the reactor includes the pneumatic system.

† Estimated cost of tile lining.

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INPUT
20 to 35V DC
at approx. 5 m.a.

OUTPUT FREQUENCY
400 or 500 cycles

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+ —.02% from —65° to + 85°C.

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OUTPUT VOLTAGE
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TECHNICAL ADVANCES

New Element: Mendelevium-101

A new nuclide, $_{101}Mv^{256(?)}$ has been produced and identified by University of California Radiation Laboratory radiochemists, Ghiorso, Harvey, Choppin, Thompson and Seaborg. Still more are anticipated. Techniques grow more complicated to match the smaller numbers of atoms available, their increased instability against spontaneous fission, and the multistep production methods required. To produce the new $_{101}Mv^{256(?)}$ $\sim 10^9$ atoms of 20-day 99^{253} were electroplated onto a thin gold foil and bombarded with a 10-μamp 48-Mev helium-ion cyclotron beam. Transmutation recoils, ejected in a narrow spray, were caught on an adjacent 0.1-mil gold foil. The catcher foil was dissolved, the gold extracted with ethyl acetate, and the remainder further purified in an anion resin column. The small residue was eluted through a cation resin column to separate the various actinide elements from each other. A few spontaneous fissions were detected at the 100 and 101 positions in the column.

A more elaborate experiment showed that there was spontaneous-fission activity at the position corresponding to element 101. The mass number is not certain, but it is probably 256 since alpha decay is expected to be more probable for odd-mass-number isotopes and alpha decay was not observed even under more sensitive conditions. Thus the production is probably by an (α,n) reaction. Decay is by electron capture to 100^{256} which then undergoes spontaneous fission with 3–4-hr half-life. Since the fission activity is observed with essentially the same half life at the 101 position the half-life of $_{101}Mv^{256}$ is deduced to be $\sim 1\frac{1}{2}$ hr. In all, only 17 atoms of the new element were isolated, which accounts for the uncertainties in mass and half-life.

. . . , 101, 102, 103, 104, . . . Discovering element 101 raises the question of the prospects for discovering the succeeding elements. B. G. Harvey has written an interesting report (UCRL-2976) on this problem. Elements 99 and 100 were produced from Pu^{239} in the high neutron fluxes of the MTR by a series of repeated neutron captures followed by β^- decays to the next higher element, but this technique will probably fail to make elements above $Z = 100$. This is so because 100^{256} fissions spontaneously with a half-life of the order of 3 hours. Thus there is little chance of its remaining around long enough to capture another neutron and make 100^{257} . . . and theory indicates that 100^{259} must be reached before the β^- decay to 101 occurs.

There are other modes of production however: element 100 has been made by bombarding uranium with cyclotron-accelerated oxygen ions, element 101 has been made by alpha-ray bombardment of 99^{253} as related above. Thus, though the numbers of atoms produced will be few and half-lives will be short, there is every reason to anticipate the identification of trans-mendelevium elements. In particular, element 103 is expected to be the last of the rare-earth-like actinides and 104 will be analogous to zirconium and hafnium. Finding these will be further tribute to Mendeleev, the first to apply the periodicity of chemical properties to the discovery of new elements, and to his scientific progeny as well.

Making Scintillators by Compaction

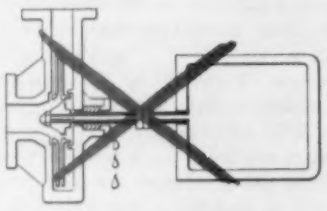
Scintillators comparable with those grown from a melt can be made by compacting microcrystalline powders. Size has been limited to cylinders about $1\frac{1}{2}$ in. in diameter and $\frac{3}{4}$ in. long, but this is not an inherent limitation. Activated microcrystalline powders are squeezed together under 100,000-psi pressure in an evacuated double-piston die. Pressures are held 5–15 min and the material removed. NaI(Tl) and KBr(Tl) scintillators have been compacted successfully, but ZnS(Ag) failed to cohere. Compacted NaI(Tl) scintillators gave 35–85% of the Cs^{137}-gamma-ray pulse height obtained with single-crystal scintillators; compacted KBr(Tl) consistently gave 90% of single-crystal.

This work was done by L. Reiffel and H. V. Watts at the Armour Research Foundation. The compacting techniques have been used previously in infrared analysis where samples are compacted with infrared-transparent alkali halides. This suggests the possibility of compacting beta-active materials in scintillators to provide standards counted in 4π geometry.

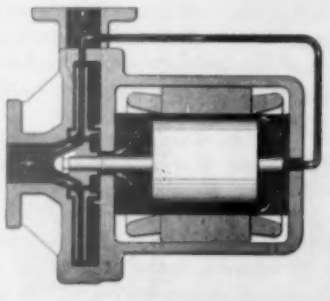
"CANNED ROTOR" PUMPS PAY OFF IN LOW UPKEEP COSTS, NO FLUID LOSSES

UNIQUE CHEMPUMP DESIGN SAVES TRICHLORETHYLENE USER $45 A DAY

Philadelphia, Pa. Officials of a large electrical switchgear manufacturer recently stated that $45 per day savings of trichlorethylene resulted from installing a Model CF Chempump on a distillation-type degreaser. Fluid losses with the ordinary centrifugal previously installed averaged 25 gallons a day. "On top of this," they stated, "we had to repack the pump every two days. We'd tried all kinds of packing, some of them very expensive—but without luck. Since installing the Chempump, we haven't lost a drop of solvent, and there has been absolutely no maintenance."



Design secret of the Chempump lies in combined construction of pump and motor, which eliminates seals, stuffing boxes, lubrication, long external shafts, etc. The Chempump allows pumped fluid to enter rotor chamber; a corrosion resistant liner isolates stator windings. Chempumps are available in sizes from 1/8 to 7½ horsepower, and in a wide variety of construction materials.



NUCLEAR SERVICE REQUIREMENTS SPUR LEAK-PROOF PUMP PRODUCTION

Less than two years ago, only one company in the country was producing and marketing a canned-rotor pump. Today, spurred on by the atomic energy program, half a dozen firms are at work on models for atomic-powered submarines, nuclear energy central stations, even atomic-powered aircraft.

To the man in the chemical process industries, all this is good news, because canned-rotor pumps can't leak. They require no shaft seals or stuffing boxes, maintenance is practically nonexistent. And leakage losses, high maintenance costs are two of the biggest headaches centrifugal pump users face.

H. T. White and D. P. Litzenberg (left), developers of the first practical seal-less "canned-rotor" pump. On the desk are plans for an extreme-pressure, extreme-temperature design.

Canned-rotor pumps came about through the efforts of two young Philadelphia engineers, now officers and directors of the Chempump Corporation. Working on principles developed before World War II, they did further research and engineering, and in 1947 began production of a seal-less, canned-rotor pump.

Even while tooling up for production of this first model, the two designers were planning variations for specific applications in the chemical process industries. Pumps were built to handle extreme temperatures and pressures as well as a variety of corrosive fluids. The pumping requirements of chemical processors were carefully studied, and steps taken toward standardization of designs to meet those requirements.

1952 saw the formation of the Chempump Corporation to build canned pumps for the chemical process industries. Experience gained from nearly 15 years of laboratory and field testing went into the design and production of products offered by this corporation. First in the field of canned-rotor pumps, Chempump is also first with pumps tailored specifically to the chemical processing industry.

PUMP SERVICE POLICY ENDS MAINTENANCE PROBLEMS

To reduce process downtime, many plants purchase a spare pump for every two, three, or five pumps installed, depending on circumstances. We feel this is a good policy, since downtime is limited to the time required to install a spare.

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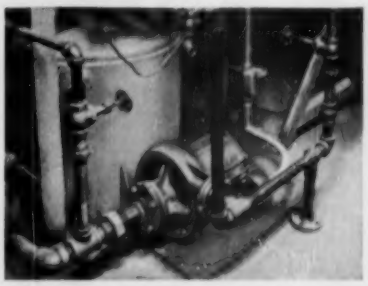

Chempump handling condensate under extreme vacuum for large Eastern chemical manufacturer. Air contamination would render system inoperative.

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R-21KR	1-10 KV	10 ma @ 5 KV	½%
R-22C	3-26 KV	2 ma @ 18 KV	——
R-22CR	5-26 KV	2 ma @ 18 KV	½%
R-22M	5-30 KV	3 ma @ 20 KV	——
R-22MR	5-30 KV	3 ma @ 20 KV	½%
*R-22SR	5-30 KV	2 ma @ 30 KV	½%
*R-52SR	5-50 KV	2 ma @ 30 KV	½%

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21K	1-10 KV	10 ma @ 5 KV	——
21KR	1-10 KV	10 ma @ 5 KV	½%
21M	1-12 KV	6 ma @ 10 KV	——
21MR	1-12 KV	6 ma @ 10 KV	½%
22C	3-26 KV	2 ma @ 18 KV	——
22CR	5-26 KV	2 ma @ 18 KV	½%
22M	5-30 KV	3 ma @ 20 KV	——
22MR	5-30 KV	3 ma @ 20 KV	½%
23C	5-40 KV	1.3 ma @ 25 KV	——
23CR	5-40 KV	1.3 ma @ 25 KV	½%
23M	5-45 KV	1.5 ma @ 30 KV	——
23MR	5-45 KV	1.5 ma @ 30 KV	½%
24C	5-50 KV	1 ma @ 35 KV	——
24CR	5-50 KV	1 ma @ 35 KV	½%
24M	5-55 KV	2 ma @ 30 KV	——
24MR	5-55 KV	2 ma @ 30 KV	½%
*23S	3-35 KV	3 ma @ 30 KV	——
*23SR	5-35 KV	3 ma @ 30 KV	½%
33S	1-30 KV	4.5 ma Entire Range	——
*52SR	5-50 KV	2 ma @ 45 KV	½%

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BOOKS

Handbook of Radiology

RUSSELL H. MORGAN, Editor, KENNETH E. CORRIGAN, Assoc. Editor (Yearbook Publishers, Inc., Chicago, 1955, x + 518 pages, $10.00). Reviewed by MARSHALL BRUCER, Oak Ridge National Laboratory, Oak Ridge, Tenn.

The editors of the "Handbook of Radiology" state in their preface that their aim has been "to present in condensed form as large an amount of accurate, reliable, and current information in the field of radiology as seemed consistent with convenience in form and the possibility of wide utility and distribution." It is hoped that this aim is revised in future editions. One of the primary uses of a handbook is that it be a ready reference to essential data that is only infrequently used. The editors have directed their efforts toward "workers engaged in clinical, experimental, and industrial applications of ionizing radiations." With so wide an objective, almost any tabular computation of data can be considered essential.

The handbook is divided into six sections and four appendices. It is difficult to see why the appendices are not considered as additional sections. Each appendix is a tabular arrangement similar to other sections of the book.

The first section consists of 59 pages of definitions of physical terms and units. The more general definitions follow the "Handbook of Chemistry and Physics," but many are written in abbreviated form. This is a fault since the major use of a handbook over that of an ordinary dictionary definition is to impart a detailed technical precision to a word. The reviewer will continue to use the "Handbook of Chemistry and Physics" for precise definitions.

A new collection of definitions, however, is included under the subtitle *Radiation*. The handbook pulls together, from a myriad of sources, all of the sometimes confusing terminology of radiation. These radiation definitions appear to have been much more carefully thought out than the others in the handbook. On the other hand, such a compilation emphasizes the need for a more careful revision of terminology by all of the national committees on radiation. For example, the word "dose" is defined completely in terms of energy imparted to tissue. This is inconsistent with the use of this same word throughout the book and certainly is inconsistent with the definitions given for "air dose," "absorbed dose," and "depth dose." The word "dose" as defined in the handbook has no meaning in its compound "surface dose."

Following the definitions in Section 1 are 12 pages of conversion tables that are expertly arranged.

Section 2 consists of general physical information. The title adds the words in parentheses "including biophysical data." There are 72 pages of physical information and 2 pages of biophysical data. This might, however, be a criticism of bioradiation-physicists rather than a criticism of the editors.

Section 3 consists of 65 pages of radiotherapeutic data. There is an excellent selection, though not complete coverage, of depth-dose data for most currently used external beams of radiation. There is a complete and concise description of radium dosimetry that to this reviewer seems better arranged and more easily understandable than most textbooks on the subject.

Section IV consists of 60 pages of miscellaneous data on radioisotopes. The decay schemes and decay characteristics are given for a few isotopes. Because decay schemes are often unknown or inaccurate, the serious investigator will still have to refer to the NBS compilation. Many of the essential data and many essential isotopes are missing. The table on beta- and gamma-ray-dosage characteristics of radioisotopes, published by Marinelli in 1947, is used rather than the much more useful revision of the same table that was published in 1950. The decay characteristics are given for 22 isotopes. Where tritium is included as a "frequently used radioisotope," the isotopes of barium, cerium, chlorine, chromium, europium, iridium, tantalum, thulium, and zenon, which are more widely used, are not included. Some of the half-lives used in calculating the decay characteristics have been out of date for some years. Although the figures are given to the third decimal place, it is obvious that this third decimal place was not rounded out but the fourth figure was merely dropped. The reviewer spot checked this handbook's tables against two other sets of similar tables, and it is obvious that either two or all three of

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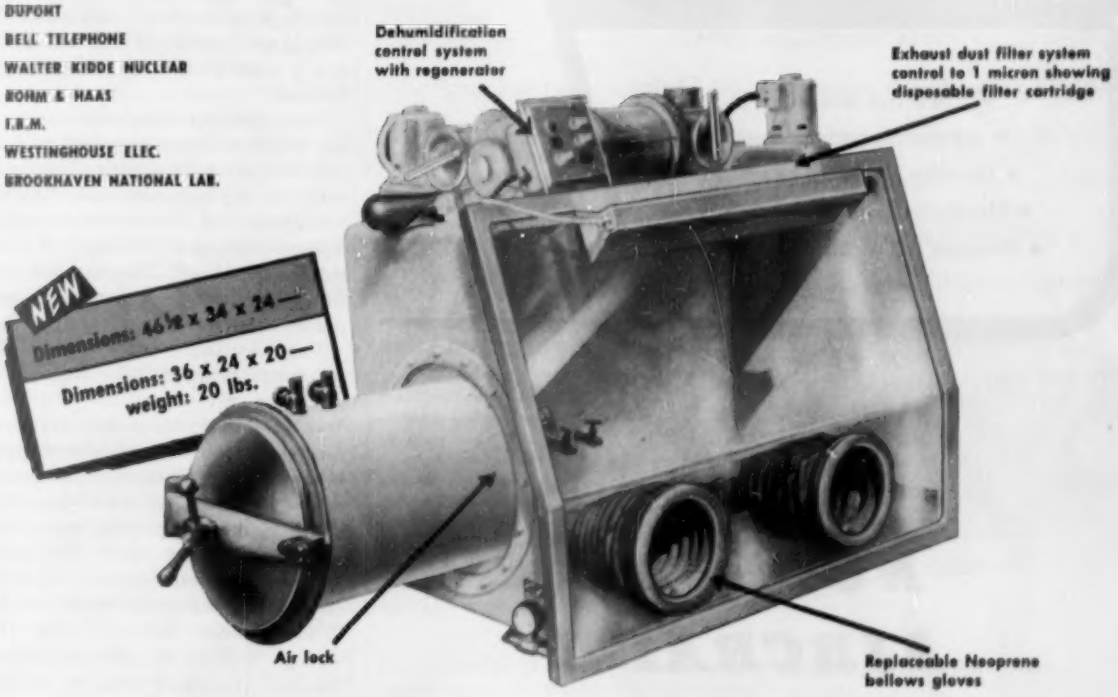
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the tables have errors. It is true that the errors are minor when one considers the practical use to which such tables are put, but one expects a handbook to be authoritative and without error.

Section 5 consists of 134 pages of materials and techniques used in radiography and fluoroscopy. The text is concisely written, the illustrations of technique are a beautiful example of precision and completeness. Section 6 consists of 65 pages under the title *Radiation Protection*. Almost all of this is concerned with protection from external irradiation; much of it is a distillation of the NBS handbooks.

Many things that the reviewer thinks are important are missing from the handbook. For example, in Appendix B a table of scale of 64 is given but there are no tables of scales of 128 and 256. These higher scales are rapidly becoming more essential with the introduction of fast counters and scintillation crystals. In some laboratories the scale of 64 is no longer used. There are no tables of densities of commonly used materials. This is the kind of tabular material that is now available only in many scattered reference books but is often wanted by persons using isotopes.

The single page of material on counting statistics with a reference to Jarrett's article is not a sufficient handbook entry for the important and often referred to subject of statistics and radioisotope counting procedures. The inclusion of a table of Chi-square is a poor substitute for the more usually used graphical methods.

The very important tables on the maximum range of beta particles is given for only a very few materials. Data in both tabular and graphical form are available and should have been included. There is no mention of fission products and their characteristics, an item of growing importance during the past few years. No discussion of decontamination methods is included, although very useful tabular discussions have been published elsewhere. Nothing is mentioned within the very important fields of neutron activation and detection. Throughout the handbook there seems to be a preponderate emphasis on externally applied radiation.

It might appear from the extent of criticism in this review that the Handbook of Radiology is inadequate. Nothing could be further from the truth. The editors have compiled a

monumental selection of tabular and graphical data that will be of permanent value to anybody working with radiation. The reviewer will recommend it to anyone who has a professional interest in radiation as the first book to buy. It has far fewer faults than can be reasonably expected of the first edition of any handbook.

In the preface of this handbook, the editors request the assistance of readers in pointing out omissions and errors. With the growing importance of the field of radiology, it is hoped that the national societies and that all workers with radiation will cooperate in the preparation of the second edition of this important milestone in radiation literature.

Nuclear Physics

By IRVING KAPLAN (Addison-Wesley Publishing Co., Inc., Cambridge, 1955, xi + 609 pages, $10.00). Reviewed by SERGE A. KORFF, New York University, New York, N. Y.

In this book, which is intended as a text, the author has written an excellent introduction to the field. The author is a physicist of standing, at the Brookhaven National Laboratory, and is well qualified to write a text on this subject. He has himself done research and made contributions in the field of the book.

The book uses calculus, and would appear to be suitable to first-year graduate-student courses; possibly advanced seniors could also benefit from it. At the end of each chapter there are appended sets of problems dealing with the subject covered, so that the student may have some experience in making the types of computation that one actually frequently meets in this field.

In developing the subject, in order not to require preceding this course with one in atomic physics, the author starts by reviewing those pertinent facts of atomic physics that underlie our views of the nucleus. He starts with a chapter on the chemical foundations of atomic theory and shows how the periodic system is built up. Then he reviews the main relations between atoms, electrons and radiation, the determination of electronic charge and the characteristic properties of radioactivity. There follows a chapter on Rutherford's scattering experiments and the resulting picture of the nuclear atom. X-rays and X-ray effects, such as diffraction and Compton scattering, are reviewed, and Moseley's law is discussed. Next he passes to the quantum theory of radiation, and the special

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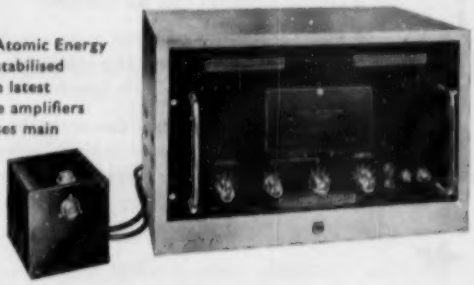

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theory of relativity. This is followed by a section on atomic spectra, so that the concept of energy levels and the basic ideas of quantum mechanics are developed.

The next section of the book is entitled *The Nucleus*, and here the author really gets into the subject represented by the title. He starts with a discussion of the constitution of the nucleus, of isotopes and of natural radioactivity and transformations. He then takes up the problems of artificial nuclear disintegrations, artificially induced radioactivity and the resulting kinds of decay. Alpha, beta and gamma decay each receive his attention for a chapter. He next takes up nuclear reactions and ends the section with a discussion of nuclear forces and the interpretation of the evidence in terms of nuclear structure.

Part 3 of the book is entitled *Special Topics and Applications*, and here there are five chapters headed *Neutron Physics, Nuclear Fission, Acceleration of Charged Particles, Nuclear Energy Sources*, and *Isotope Separation*. In the section on energy sources, he discusses reactors of various kinds, and various cycles that are known in astrophysical theory as energy sources. Such concepts as critical sizes, and power production and breeding, all useful in nuclear engineering courses, are introduced.

At the end he has three appendices, listing the elements, the physical constants, the journal abbreviations used, and a nuclide chart that is included as a separate item at the end. The book is well indexed. Many other tables of values, such as isotopic abundances and masses are to be found in the body of the text.

In judging the potential merits of a book, a reviewer is inclined first to ask what group the book is intended to serve, and then to see how it goes about serving them. This book is evidently intended for two groups of people, first the students who would use it as a text, and second, persons who are engaged in working on the engineering fringes of nuclear physics.

Applying these criteria to the book in question, we see therefore that it covers, on a level which all these people may be expected to have attained, the subject of nuclear physics. Indeed the background covered before the main subject of nuclear physics itself is broached, is sufficient so that the student can, by using the book, learn about the subject without first having

to take a course in atomic physics or modern physics. The subject matter is comprehensively covered, the tables and data are satisfactory. About the only subject that seems to have been slighted is that of the detection instruments, which are so important in evaluating the characteristics of nuclear radiation. These receive only brief mention in this text.

On the whole, it seems to this reviewer that the book is a most useful one, and is certainly a most welcome addition to the still scant set of books in this field. It is well written, authoritative, and will form a good and a useful text. It will also constitute a useful and welcome addition to the library of persons working in this field.

Isotope Geology

By KALERVO RANKAMA (McGraw-Hill Book Co., Inc., New York, 1955, xvi + 535 pages, $12.00). Reviewed by P. M. HURLEY, Massachusetts Institute of Technology, Cambridge, Mass.

This long-awaited book on isotope geology by Professor Rankama lives up to expectations. It reflects the same thoroughness and complete coverage of the literature that he has shown in his previous writings on geochemistry. It is difficult to present a subject such as this to a branch of science for the first time because of the need of sufficient preparatory coverage of the physical and chemical bases of the subject for all readers. The author has achieved this objective very well by dividing the book into two parts, the first of which covers the elements of nuclear physics and chemistry and the second of which is concerned with the geochemistry of isotope abundance variations.

In Part 1 there are ten chapters covering the general aspects of the physics and chemistry of atomic nuclei. Starting with the structure of atoms and nuclei, the author progresses into the distribution and abundance of nuclides in nature, and into the general question of possible methods of isotope fractionation by natural processes. This is followed by a section on mass analysis by physical means and by neutron activation. The applications of such analyses to the science is discussed briefly in a general way, with detailed discussions in the second part of the book on those applications of particular interest to geology.

There follows a section on radioactivity similar to a number of brief treatments of this subject that have appeared in books recently. This in-

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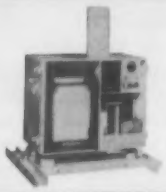

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cludes a description of the processes of radioactive decay, natural radioactivity, artificial radioactivity and the properties of ionizing particles and radiation and their interaction with matter. Also included is a short section on neutrons and their range and absorption.

A short chapter covers nuclear reactions in nature, including natural fission and the production of nuclides by cosmic radiation. Getting more into the field of interest, the author discusses at some length geological applications of radioactivity. The distribution of radioactivity in igneous rocks leads to a study of radiogenic heat production in rocks. This is followed by a general description of geologic age measurement, the age of the earth and of the elements. Applications of radioactivity are then discussed, in such subjects as the rate of deposition of ocean sediments, the process of metamictization, the genesis of petroleum, well-logging, and the use of radioactive tracers in laboratory research. Part 1 is concluded by a discussion of the terrestrial abundance of elements versus the cosmic abundance of elements and nuclides, and the origin of elements; and a further discussion of isotope fractionation in nature.

Part 2 is made up of an extensive coverage of information concerning the isotopes of almost every element. Each chapter covers a different element. Most of the elements require very little more than a list of the isotopes and a statement of their radioactive abundance in nature. The principal chapters cover the elements that have been found to exhibit significant changes in the abundance of their isotopes either from natural fractionation processes or from the effects of natural radioactivity or nuclear reactions. The principal chapters are those concerned with hydrogen, helium, carbon, nitrogen, oxygen, sulphur, argon, potassium, calcium, rubidium, strontium, lead, thorium and uranium. These major chapters are of principal interest to the geologist and the geophysicist, and represent thorough compilations of measurements and discussions in the published literature. For example, in the chapter on carbon, the author goes into the variations in the ratio of C^{12} to C^{13} in meteorites, the atmosphere, the hydrosphere, the lithosphere, and the biosphere, and discusses these variations and their applications to the understanding of geological processes. He also discusses the variations in the

abundance of C^{14} and the method of age measurement resulting from this. Numerous tables are given on the variations of the stable carbon isotopes. Similarly, in other major chapters a detailed listing of the evidence, and the inferences drawn from the variations of isotopes is presented within the very broad framework of the author's geological knowledge.

Like Rankama's previous works, the book is an extraordinarily complete compilation and summary of the published literature. The bibliography runs to 44 pages with 25–30 references per page. The appendix also contains a similarly comprehensive name index and a subject index of 46 pages, covering a wide area of subject matter. For these reasons the book is an excellent reference text.

In keeping to a completeness of plan, the author has to some extent buried the interesting chapters in a large amount of detail, which makes the book a little less manageable in classroom use. However, selected readings from the book would adequately cover the range of activities in this branch of the science.

Radiation Biology, Vol. 2

ALEXANDER HOLLAENDER, Editor (McGraw-Hill Book Co., Inc., New York, 1955, x + 593 pages, $8.00). Reviewed by ROBERTS RUGH, College of Physicians and Surgeons, Columbia University, New York, N. Y.

This review volume, published under the auspices of the Committee on Radiation Biology of the National Research Council, contains 14 chapters written by 17 different author-specialists. More than half of the chapters deal with ultraviolet radiations, from photochemistry through techniques in research to the production of cancer. The balance of the book is related only by virtue of the fact that it deals with organisms within the microscopic range, such as viruses, fungi, bacteria, protozoa and invertebrate eggs and organisms.

The types of radiation discussed include some high-energy studies in addition to the ultraviolet. The excuse for the particular grouping of subjects is that both parts of the spectrum have similar biological effects, so that the common denominator, if one can be discerned, is "the lower organisms." One chapter on *Sunburn* and another on *Ultraviolet Radiations and Cancer*, which are exceptions, are tucked in as concluding chapters. They deal with

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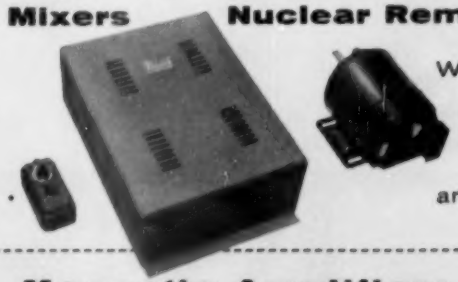

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the mammal, but probably these chapters could not be included in any other volume.

Four of the 14 chapters are quite academic, reading in textbook fashion, and would be of value to novices in the field of radiation biology. Practically every other chapter concerns material of the last decade, up to 1951. A fine example is chapter 6 by Pollister on *Critique of Cytochemical Methods* in which 98 of the 144 references are dated since 1940. Cytochemical methods are largely of recent origin, but this same tendency to discuss the subject in light of current research is shown by Kimball in his chapter on *The Effect of Radiations on Protozoa and the Eggs of Invertebrates and Other Insects.* In this latter field there is an abundance of earlier literature, but the author has brought the subject up to date.

One might wish for a concluding, summarizing chapter written by someone capable of assembling, digesting, and presenting the salient features of recent research in radiation biology of the lower organisms. There is a valiant attempt in this direction, at the end of chapter 10 by Zelle and Hollaender, in their discussion of the mechanism of radiation effects. They attribute lethality of radiations among lower organisms to an indirect, rather than direct, effect of radiations. By indirect action is generally meant that chemical intermediates are produced by the radiations and these subsequently react with the biologically significant materials, producing mutations or lethality or both. The authors are disturbed by the independence of the bactericidal effect and intensity and the lack of large temperature coefficient that is generally characteristic of chemical disinfectants. The poison produced by radiation (UV or high energy) may "indirectly" produce within the cell an internal poison that is quite different from an externally applied chemical disinfectant.

The authors seem to feel that the nucleus is the sensitive target, and the term "lethal mutation" (heritable genic change), used quite frequently, is difficult to distinguish from lethal action of radiation. The end result may be the same, i.e., a dead cell, but in the instance of a lethal mutation, the killing process is related to its reproductive processes. It is of interest to note that the tendency is away from the older, classical explanation of direct action of the rays on the vital elements of the cells. This is in part due to the

failure of many sets of data to fit into the target theory.

Radiation and Viruses by Luria and *Photoreactivation* by Dulbecco are also chapters that many readers will be happy to find.

One gets the impression that the editor found it difficult to associate the material of some of the chapters, but in spite of the lack of a common denominator throughout the book, he decided (and rightly) that the recent researches in the field of radiation biology of the lower organisms were so important that the unity of the book as a whole was relatively unimportant. This may suggest the diversity of research in the field, a field that, though still in its infancy, has a very promising future.

Framework for Atomic Industry

By HERBERT S. MARKS and GEORGE F. TROWBRIDGE (BNA, Inc., Washington, D. C., 1955, viii + 276 pages, $12.50). Reviewed by EVERETT L. HOLLIS, General Electric Co., New York, N. Y.

Atomic energy has so often carried with it connotations of mushroom clouds, security clearances, and complex Einstein equations—a subject, which even if not enshrouded in secrecy, could be understood by only a few Ph.D.'s. And anyway, why bother to find out more about the atom!

The promise of atomic energy for civilian purposes is changing these attitudes. There are now positive incentives for businessmen, investors, lawyers and others to learn about the atom—and find out, for example, whether atomic energy might offer commercial opportunities, how it might affect investments, and how it will be regulated by Government. The increasing thirst for knowledge about the atom is well exemplified by the demand for, and the large attendance at, recent conferences and meetings sponsored by organizations like the Atomic Industrial Forum and the National Industrial Conference Board.

There is a growing realization that any real exploration of the commercial possibilities of the atom means more than learning about neutrons and reactors. It is also important to understand what Government rules and regulations will govern commercial atomic activity. This new book, "Framework for Atomic Industry—A Commentary on the Atomic Energy Act of 1954" by Marks and Trowbridge, will be of great value to anyone desiring

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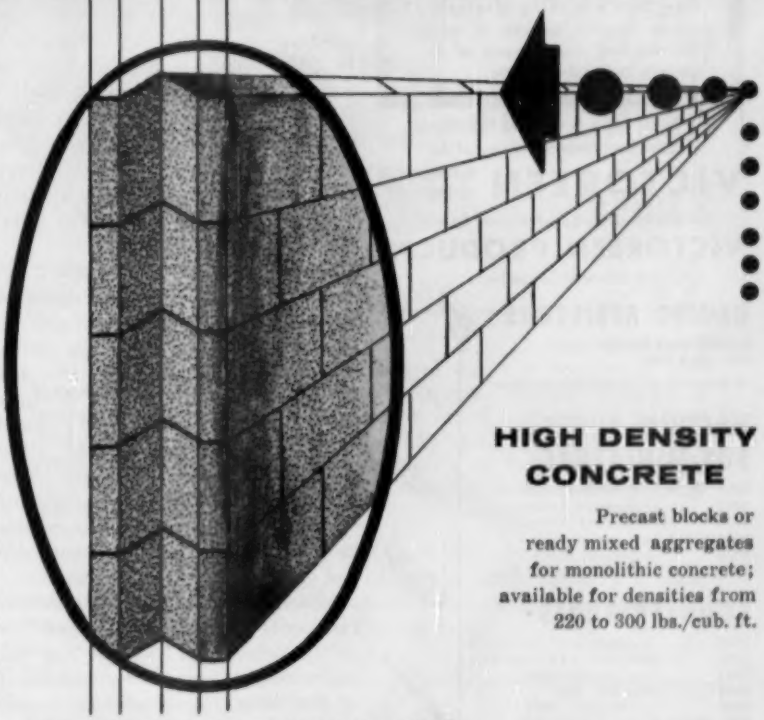

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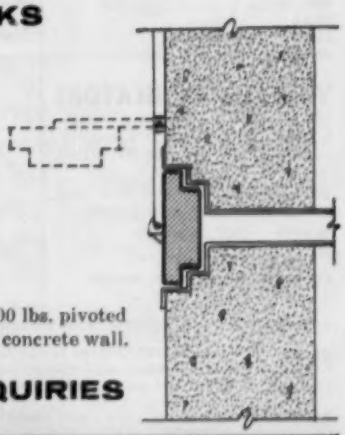

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a general understanding of the new Atomic Energy Act and its background. Both authors were formerly counsel to the Atomic Energy Commission, and both have been close observers of legal and legislative developments affecting atomic energy.

This book consists of two main parts, the first of which contains a clear and concise discussion of the major changes that the 1954 Act made in the previous law. This part includes, for example, a discussion of the provisions in the new Act relating to the control of facilities, materials, and information. It also contains a discussion of the patent provisions, and provisions relating to power policy, Government aid to industry, international activities, and organization of the Atomic Energy Commission, as well as the important role of the Congressional Joint Committee on Atomic Energy.

The second part of the book is devoted to a more detailed analysis of the regulatory system envisaged by the new Act. This includes a discussion of the licensing of reactors and other atomic facilities, the licensing of source material, fissionable material (called special nuclear material in the Act), and by-product material. This second part also includes comments on the enforcement measures available to the Atomic Energy Commission and on administrative procedures.

The usefulness of the book is greatly enhanced by the inclusion in appendices of the full text of the new Act, the earlier 1946 Act, and the official report of the Joint Committee on Atomic Energy concerning the new Act (including the Conference Reports). The reader will also be grateful for the inclusion of an index.

This book is far from being a legalistic report on the words of the Act. On the contrary, it stresses the broad discretionary authority granted to the Atomic Energy Commission and endeavors, in a number of places, to suggest how the Commission will exercise its administrative discretion. Furthermore, the authors have explained the meaning of terms that are not used in the Act itself but that are an essential part of the vocabulary of anyone who wants to understand the regulation of the atomic industry, e.g., what L clearances and gray areas are. Also the authors have identified particular problem areas in the Act and, in some instances, have indicated likely or possible solutions to the problems.

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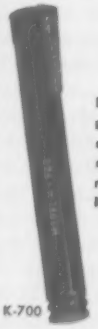

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As Marks and Trowbridge put it: "He who would understand must . . . know first what the policies of the Congress are and what they signify, and further he must know what the Executive is doing and is likely to do in carrying out Congress' policies." This book will certainly assist anyone to achieve a better understanding, whether he be a novice or a veteran in the ways of the atom.

BOOKS RECEIVED

American Men of Science, I—The Physical Sciences, edited by Jaques Cattell (The Science Press, Lancaster, and R. R. Bowker Co., New York, 1955, 2180 pages, $20.00). This first volume of the 9th edition contains 43,518 names. The second and third volumes, "Biological Sciences" and "Social Sciences," should bring the total to about 90,000 names. In cases such as biophysics, where the biography could be entered in two volumes, the name appears in both with a reference to the volume containing the biography.

Magnetic Amplifiers, by Herbert F. Storm (John Wiley & Sons, Inc., New York, 1955, xix + 545 pages, $13.50). This book is written by a number of General Electric authors for "practicing electrical engineers and senior students of electrical engineering." The sections are *Magnetics, Theory of Magnetic Amplifiers, Components,* and *Applications.*

The Elements of Chromatography, by T. I. Williams (Philosophical Library, New York, 1955, 90 pages, $3.75). The chapters of this book include: adsorption, partition, ion-exchange, and other miscellaneous forms of chromatography, treatment of colorless substances, developing the chromatogram, and industrial applications.

University Physics, 2nd edition, by F. W. Sears and M. W. Zemansky (Addison-Wesley Publishing Co., Inc., Cambridge, 1955, viii + 1031 pages, $10.00). This is a new edition of a solid, widely adopted elementary physics text. Optics is assigned 147 pages while nuclear physics is assigned 15 pages. In light of the growing importance of nuclear energy, one might hope for more attention to it.

Linearized Theory of Steady High-Speed Flow, by G. N. Ward (Cambridge University Press, New York,

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602	30 to 400	100-300-1000	10 to 9990	x-ray therapy
603	400 to 1300	5000-15,000-50,000	500 to 499,500	On telecurie gamma sources
604	10 to 30	100-300-1000	10 to 9990	Low energy therapy
605	400 to 1300	1-3-10	0.1 to 99.9	Gamma ray sources
606	400 to 1300	10-30-100	1 to 999	Gamma ray sources
607	400 to 1300	100-300-1000	10 to 9990	Gamma ray sources
608	30 to 400	1-3-10-r/hr.	1 to 999 / 600	Survey in vicinity of x-ray machines.
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1955, xv + 243 pages, $6.00). This monograph presents the current status of the linearized theory for applied mathematicians and aerodynamicists. It develops the theory for steady flows and then discusses specific boundary-value problems and their solutions.

ALSO OF NOTE

AEC publishes fall-out data. Extensive measurements of fall-out in the United States to Jan. 1, 1955 from atom-bomb tests reveal the resultant levels of radioactivity to be below natural background. That is the essence of a report published in *Science* (May 13, '55, p. 677) by Merril Eisenbud and John H. Harley of the Health and Safety Laboratory of the U. S. Atomic Energy Commission.

During test periods, all of the United States except within 200 miles of the Nevada test site are monitored by a network of 89 sampling stations. At all other times the number of stations is reduced to 41, since debris from extra-continental tests is more diffused.

The monitoring technique (NU, May '52, p. 10) has a sensitivity such that a fall-out of 10 dpm/ft²/day can be detected. Since a fall-out of 10^6/dpm/ft² results in a general rise in gamma background of $\frac{1}{10}$ mr/hr, the detection limit of this monitoring scheme corresponds to 10^{-6} mr/hr. This is $10^{-4}\times$ normal gamma background, due to cosmic rays and natural radioactivity, which is around 10^{-2} mr/hr.

Based on 250,000 samples collected since 1951, the accumulated fission products deposited throughout the country (in mc/square mile) averages 61 and ranges from 21 in Arizona to 120 in New Mexico. The fall-out is less than natural radioactivity on the earth's surface. Naturally occurring Ra^{226}, alone, in the upper few inches of the earth's crust is present in amounts of 100–1,000 mc/square mile.

The gamma-ray dose corresponding to a 120-mc/square-mile fall-out is of the order of 0.001 mr/hr, which is less than natural background of 0.005–0.05 mr/hr. Rain can precipitate anomalously large amounts of radioactive debris, but in no instance outside the 200-mile test area has this exceeded a cumulative dose of 100 mr.

The 25-yr half-life of Sr^{90} and the fact that it is treated like calcium in biological systems make it important to consider this isotope separately.

By September 1, 1954, the estimate of accumulated Sr^{90} was 3 mc/square mile. This is one-millionth of the amount AEC estimates to be required for recognizable biological effects.

Russian experiments with a 660-Mev synchrocyclotron. A group of 7 Russian papers, from *Doklady* **99,** No. 6 (Dec. 15, 1954), on experiments with a 660-Mev synchrocyclotron has been translated by M. Hamermesh. These articles reveal Russian high-energy-research techniques to be comparable with those employed in America. Scintillation counters, fast electronics, and bubble chambers are used in much the same experimental arrangements. Also of note is the fact that the Institute for Nuclear Problems, where the work was carried out, had a 460-Mev proton synchrocyclotron in 1952, and one in excess of 660 Mev in the summer of 1954. This is much below the 6 Bev of the Berkeley bevatron, but shows the Russians to have been abreast in 1952.

A technical analysis of the Russian articles, prepared for NUCLEONICS by R. P. Shutt of Brookhaven National Laboratory, follows.

Four of the articles, appearing under different combinations of the names of Bogachev, Bogomolov, Meshcheryakov, Neganov, Nikitin, Piskarev, Selektor, Soroko, Vzorov, and Zombkovsky, deal with angular distributions for elastic scattering of protons by protons at energies ranging from 460 to 660 Mev. Scintillation counters were used to measure differences in scattering between paraffin and carbon.

At 460 Mev the scattering is found to be almost isotropic; the ratio, R, of the differential cross sections at 30 and 90 deg is 1.2. At 610 Mev R has increased to 2.2, and at 660 Mev to 3.2. It is suggested that the very rapid increase of R between 610 and 660 Mev is partially caused by a resonance effect similar to that observed in pion-proton scattering at corresponding center-of-mass energies. The total elastic cross section between 460 and 660 Mev is found to be essentially constant, 22 millibarns. On the other hand, inelastic cross sections, mostly resulting in meson production, are 6 millibarns at 460 Mev and 18 millibarns at 660 Mev, making use of results by Shapiro, Leavitt, and Chen (Brookhaven). The large inelastic cross section at 660 Mev must lead to diffraction scattering which further contri-

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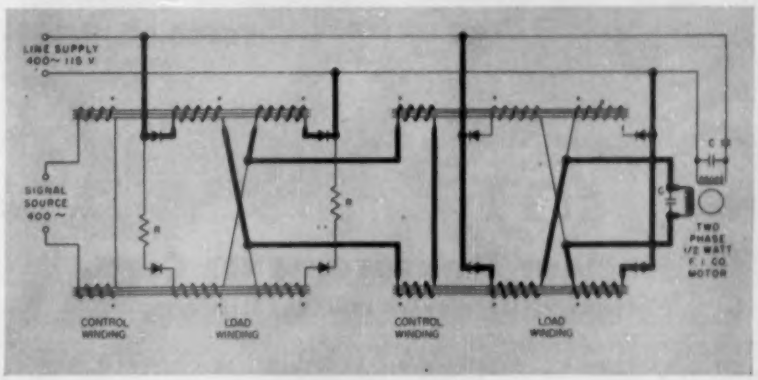

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In the circuit shown here, amplification in each stage of the amplifier is accomplished by pre-setting the core fluxes with the control-winding signal during one half-cycle of the applied load-winding voltage. During the next half-cycle, when the load-winding conducts, the control winding contribution is negligible. In this mode of operation the control winding of each stage of the amplifier receives its signal during the reset or non-conducting half-cycle of that stage of amplification. The effect of this signal occurs during the next half-cycle, thus the time constant in the stage is at a minimum of ½ cycle.

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butes toward the observed deviations from isotropy.

In a further paper by Dzhelepov and Kazarinov, elastic scattering of 380-Mev neutrons by protons is investigated. The total scattering cross section is found to be 40 millibarns. The angular distribution varies slowly between 50 and 130 deg but outside this interval shows the characteristic peaking already observed by others at lower energies. It is concluded that at high energies strong interactions between nucleons occur in the isotopic spin state $T = 1$ and that exchange and ordinary forces contribute about equally.

A 300-Mev neutron-neutron experiment was performed by Dzhelepov, Golovin, and Satarov. The D_2O-H_2O difference is observed for elastic scattering. The total elastic cross section is estimated to be 22 millibarns and the angular distribution between 50 and 90 deg is isotropic, both in agreement with proton-proton scattering, which is consistent with the charge-independence hypothesis. Agreement with the Russian results is found where other data for comparison are available.

Finally, a propane bubble chamber of the Glaser type is described by Blinov, Krestnikov, and Pershin. The glass chamber, 1.6 cm i.d. and 5.5 cm long, was exposed to radiation from the accelerator, and photographs of tracks were obtained. It is found that in their operation of the chamber the bubbles grow more slowly than in Glaser's experiments, facilitating control of the chamber. *The number of copies of the translation is very limited; copies may be obtained by writing to the physics division of Argonne National Laboratory, Lemont, Ill.*

Charged-Particle-Cross Sections Compilation. Cross sections for scattering, capture, and all other nuclear reactions initiated by charged particles of energies up to 30 Mev will be published in a new compilation similar to AECU-2040, the neutron-cross section compilation. Deadline is in about 6 months. Data are being assembled from individual experimenters as well as from published articles. In its initial form, the presentation is mostly on a linear scale; both laboratory and center-of-mass-system data are given, although often the cm data are left in tabular form. Subnuclear particles are excluded. The data are being compiled by 18 staff members at Los Alamos under the sponsorship of the AEC Nuclear Cross Section Advisory Group.

NEWSMAKERS

Ralph Singleton of Brookhaven National Laboratory's biology department joins the University of Virginia September 1 as Miller professor of biology. He also will be director of the Blandey Experimental Farm at Boyce, Va., and will study radiation effects there with a cobalt-60 source.

Theos J. Thompson will direct construction of the Massachusetts Institute of Technology research reactor. Formerly in charge of design and construction of the Omega West reactor at Los Alamos, he has been named as an associate professor of nuclear engineering at MIT.

B. A. Schmickrath, assistant chief engineer at Pratt & Whitney, is in charge of the firm's nuclear-propulsion laboratory at East Hartford, Conn.

Edwin E. Ferguson has been named deputy general counsel for the Atomic Energy Commission. He succeeds **Harold Price,** now director of the division of licensing.

Abraham Edelmann, of Brookhaven National Laboratory's biology department, and **Charles W. Stanley,** of Walter Kidde Nuclear Laboratories, have joined Nuclear Science and Engineering Corp., Pittsburg, Pa.

Walter Bedell Smith has been named chairman of the board and president of AMF Atomics, Inc., newly formed subsidiary of American Machine and Foundry that will handle the company's atomic energy operations. **Arthur V. Peterson** is vice president for operations. Board members include **George S. Hills, Murray McConnel, Stanley deJ. Osborne,** and **Eugene Zuckert.**

William A. Robba heads a newly formed nuclear engineering group within the research department of Raytheon Manufacturing Co., Waltham, Mass. He formerly was a member of Brookhaven National Laboratory's nuclear engineering department.

John F. Haines, formerly vice president and chief engineer of the McCauley Industrial Corp., has joined American Locomotive Co. as chief development engineer, atomic products.

E. R. Piore, formerly chief scientist and deputy chief of the Office of Naval Research, has been named vice president of Avco Manufacturing Corp., and chairman of its committee on advanced scientific research.

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Thompson (BS, M.I.T.; Doctor of Engineering M.I.T.) went into atomic energy after helping develop the fluid catalytic cracking process at Standard Oil Development. For the Manhattan District Project, he was in charge of process development for a U-235 centrifugal separation plant. He worked on the gaseous diffusion process, went to England during the war to evaluate British pilot plant results.

More recently, as Chief Engineer of WALTER KIDDE NUCLEAR LABORATORIES, his interest in nuclear power has continued. He's headed up engineering studies on a variety of power producing facilities—particularly as regards making atomic power competitive.

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UN Titles

(*Continued from page 77*)

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38. U in Marine Black Shales of the U. S.
39. Environment of accumulation of the Chattanooga shale
40. U in the Chattanooga shale of eastern Tenn.
41. Uraniferous black shales in the northern Rocky Mountains and Great Plains regions
42. U-bearing coal in the U. S.
43. Trace elements in coal in the Red Desert, Wyo.
44. U-bearing lignite and its relation to volcanic tuffs in eastern Montana and the Dakotas
45. Portable instruments for beta-ray dosimetry
46. Measurement of tissue dose as a function of specific ionization
47. A gamma-insensitive semiconductor fast-neutron dosimeter using single-crystal Ge
48. Recent developments in the scintillation-counter field in the U. S.
49. The theory of cavity ionization
50. Methods of measurement of neutron flux at low levels
51. Neutron and gamma-ray dosimetry of a thermal-neutron irradiation facility
52. Neutron dosimetry
53. Methods of pulse analysis
54. The role of liquid scintillators in nuclear medicine
55. Liquid scintillation counting of natural radiocarbon
56. Mechanical arms incorporating a sense of feel for conducting experiments with radioactive materials
57. Absolute dosimetry of Co^{60} gamma rays
58. Dosimetry of ionizing particles
59. Irreversibility of damage produced by alpha emitters
60. Experimental data useful in establishing maximum permissible single and multiple exposures to Po
61. The potentiated lethal action of radioisotopes used in combination
62. Radiation dosage to lungs from ^{222}Rn and its daughter products
63. Hazards to the embryo and fetus from ionizing radiation
64. Studies on protection by treatment before and after exposure to X- and gamma radiation
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66. Studies on the biological basis of radiosensitivity
67. Medical care of wounds contaminated with radioactive materials
68. Industrial hygiene of U processing
69. Transportation of large quantities of radioactive materials
70. Relative biological effectiveness
71. The deposition of radioactive substances in bone
72. Maximum permissible exposure standards
73. Radioisotopes in animal physiology and nutrition-mineral metabolism
74. The mechanism of gastric acid secretion as revealed by radioisotopes
75. Time relation between K^{42} outflux, action potential and contraction phase of heart muscle as revealed by the efflluogram
76. Isotopes in research on animal nutrition and metabolism
77. Use of partial-cell irradiation in studies of cell division
78. Use of I^{131} and thyroxine to determine the thyroid hormone secretion rate of intact animals
79. Respiratory C^{14} patterns and physiological state
80. Studies on the mechanism of phytohormone damage by ionizing radiation
81. Metabolism of radioisotope-labeled drugs
82. Studies of brain K in relation to the adrenal cortex
83. Use of radioisotopes in tracing fungicidal action
84. Ionizing radiations as a tool for plant breeders
85. Neutron and gamma radiation as applied to measuring physical properties of soil in its natural state
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89. Utilization of radioisotopes in resolving the effectiveness of foliar absorption of plant nutrients
90. The comparative effect of radiation and hybridization in plant breeding
91. S^{35} absorbed by the peanut fruit
92. Use of isotopes for determining the availability of chelated metals to growing plants
93. The contribution of radiation genetics to crop improvement
94. Use of labeled compounds in weed research
95. Uptake and transport of mineral nutrients in plant roots
96. *In situ* measurement of soil bulk density
97. Applications of radioisotopes to chemical problems
98. Radioisotopes in the study of fluid dynamics
99. A high-level dosimeter for the detection of beta and gamma radiation and thermal neutrons
100. The development and design of a series of precision radioactive airborne particle detectors for health-monitoring and control systems
101. Development of direct-reading chemical dosimeters for measurement of X, gamma, and fast-neutron radiations
102. Dosimetry of reactor radiations by calorimetric measurements
103. Use of the Fricke ferrous-sulfate dosimeter for gamma-ray doses in the range 4 to 40 kr
104. Beta-ray-excited X-ray sources
105. Medical scintillation spectrometer
106. Visualization of gamma-ray emitting isotopes in the human body
107. High-resolution radiation detectors in research
108. The use of radioactive tracers for studying absorption from solution by fibrous materials
109. Industrial inspection with reactor isotopes
110. Stable and unstable isotopes in heterogeneous catalytic reactions
111. Portable isotopic X-ray units
112. Radioisotopes in petroleum refining
113. Technology and economics of high-intensity ionizing radiations
114. The effect of gamma radiation on some chemical reactions of possible industrial importance
115. The direct conversion of radiation into electricity
116. Use of radioisotopes in the production of self-luminous compounds
117. Nuclear batteries—a survey
118. Sterilization of medical supplies with gamma radiation
119. Industrial utilization of fission products
120. Use of the nuclear reactor for neutron-capture therapy of cancer
121. The use of isotopes in biochemical and medical research
122. Teletherapy devices with radioactive isotopes
123. The use of radiosodium and radiopotassium tracer studies in man
124. Scanning of positron-emitting isotopes in diagnosis of intracranial and other lesions
125. Radioisotopes in hematologic therapy
126. Dental uses of radioisotopes
127. The measurement of thyroid gland uptake and turnover of I^{131} in man by external counting: its use in diagnosis and treatment of thyroid disorders
128. Radioiodine or surgery in the treatment of thyrotoxicosis
129. Possibilities and limitations of *in vivo* external counting techniques in biology and medicine
130. Tissue specific antibodies as carriers of radioactive materials for the treatment of cancer
131. Isotope therapy for carcinoma of the pancreas
132. Radiation hypophysectomy and related studies using 190-Mev deuterons and 340-Mev protons
133. Versatility of radiogold in treatment of malignant disease
134. A Sr^{90} surface applicator designed for treatment of corneal lesions and evaluation of biological effects
135. Diagnostic procedures
136. I^{131} therapy of hyperthyroidism
137. Physiological and biochemical studies of At^{211} and their possible therapeutic applications
138. Radioisotope use in medical diagnosis
139. Radiation hypophysectomy using Y^{90} pellets

140. Co^{60} teletherapy isodose patterns for combined and nonuniform longitudinal and transverse source motions
141. The distribution and excretion of U in man
142. Studies on the metabolism of tubercle bacilli and their fate after phagocytosis
143. Use of radioactive metabolites in studying the modes of action of anticancer agents and searches for exploitable biochemical differences between normal and cancer cells
144. The use of radioactive tagged red cells and platelets to study the phenomenon of sequestration
145. The stability of human serum lipoproteins as measured with P^{32}
146. Biochemical changes of experimental precancer. Amino-acid metabolism in the isolated perfused rat liver studied with the aid of lysine-6-C^{14} and histidine-2-C^{14}
147. The application of radioisotopes to the study of cancer induction
148. Absence of amino-acid incorporation into antibody during the induction period
149. Metabolic fate of internally and externally labelled protein antigens
150. Preliminary observations on the clinical use of Co teletherapy
151. Mechanism of U poisoning
152. Internal emitters and tumor induction
153. Liquid-metal heat-transfer predictions
154. Tritium as a research tool in chemistry and industry
155. Low-level counting and the future of isotopic tracers
156. Radioisotopes in petroleum-production research
157. Versatility of radiation applications involving penetration or reflection
158. The role of radioisotopes in immunologic investigation
159. Therapeutic usefulness of radioactive colloids; comparative value of Au^{198}, chromic phosphate (P^{32}), Y^{90} and Lu^{177}
160. Treatment of incapacitated euthyroid cardiac patients with I^{131} (summary of results in treatment of 1,070 patients with angina pectoris or congestive failure)
161. Carcinoma of the cervix: results obtained from the irradiation of the parametrium with colloidal Au^{198}
162. Integration of a radioisotope program into medical-school research and teaching
163. Artificial radioisotopes in Nylon ribbons for implantation in neoplasms
164. Kilocurie revolving Co^{60} unit for radiation therapy
165. Utilization of nuclear energy in public health problems on the epidemiology of communicable diseases
166. Health protection against food-borne parasitic diseases with particular reference to control of trichinosis
167. Radioisotopes as tools in sanitary engineering research
168. Absorption of radioiron-labeled foods and inorganic iron by normal, iron-deficient, and hemochromatotic subjects
169. The use of radioactively labeled compounds in study of metabolic interrelationships of host and parasitic helminths
170. Use of radioisotopes in studies of health hazards in the U mining industry
171. Use of I^{131} as a tracer in studies of sewage oxidation ponds
172. Use of C^{14} to study organic absorption properties of activated carbon
173. Radiometric methods for drinking water analysis
174. How radiation changes genetic constitution
175. Genetic effects of radiation in mice and their bearing on estimation of human hazards
176. Genetic differences in longevity and disease resistance in animals under irradiation
177. Relation between radiation dosage and chromosomal changes
178. Genetic structure of mendelian populations and its bearing on radiation problems
179. Radiation exposure experience in a major atomic-energy facility
180. Lymphocytes with bilobed nuclei as indicators of radiation exposures in the tolerance range
181. Delayed toxicity of Ra deposited in skeletons of humans
182. A formulation of the relation between radiation dose and shortening of life span
183. Validity of maximum permissible standards for internal exposure
184. Radiation protection in reactor and chemical-processing plants

(Continued on next page)

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A versatile, self-contained yet moderately priced ratemeter, the BN. 102 can be used for normal counting and health monitoring purposes with a wide variety of scintillation or Geiger counters. The instrument incorporates a pulse amplifier, discriminator and variable stabilised E.H.T. supply. It is mounted on a standard 19" panel with controls designed for ease of operation.

- *Count ranges:* 0 - 10, 100, 1,000, 10,000 *counts/sec.*
- *Electro-mechanical register for low rate counting*
- *External connections for scaler, recorder and quench unit*
- *Loudspeaker for aural indication*

BURNDEPT

The BN. 102 is one of a range of nucleonic instruments designed and manufactured by Burndept Limited. We welcome enquiries for any form of laboratory or industrial nucleonic instrumentation. For further particulars, write to Dept. N.

BURNDEPT LTD · NUCLEONICS DIVISION · ERITH · KENT · ENGLAND

UN Titles

(Continued from page 127)

185. Effect of noncellular preparations on survival after lethal doses of X-radiation
186. Early radiation death
187. Relationship between electrolytes and radiation effects on cell metabolism
188. Studies on hyperferremia following acute whole-body X-irradiation
189. Effects of whole-body exposure to nuclear energy on life span and efficiency throughout life
190. Effects of daily low doses of X-rays on spermatogenesis in dogs
191. Health protection of U miners and millers
192. The photosynthetic cycle
193. Dietary factors in the oxidation and synthesis of fatty acids by tissue preparation
194. Effects on plants of chronic exposure to gamma-s from Co^{60}
195. Distribution of C^{14} O_2 incorporated into rat live glycogen
196. Application of C^{14} to studies on bacterial photosynthesis
197. Isotopic studies in cholesterol metabolism
198. Radioactive oxtetracycline: mode of synthesis, properties and uses for the radioactive compound
199. Biosynthesis of C^{14}-labeled plants and their use in agricultural and biological research
200. Use of I^{131} in study of influence of climatic factors on thyroid activity and productivity of livestock
201. Absorption of fission products by plants
202. Radiation exposures from environmental hazards
203. Accumulation of radioactive substances in aquatic forms
204. Radioelements and their daughter products in Texas Panhandle and other oil and gas fields in U. S.
205. The aluminum phosphate zone of the Bone Valley formation and its U deposits
206. Distribution and occurrence of U in the calcium phosphate zone of landpebble phosphate district of Florida
207. U in precipitates and evaporites
208. Mineralogy and oxidation of Colorado Plateau U ores
209. Interpretation of the $Pb^{206}/U^{238} < Pb^{207}/U^{235} < Pb^{207}/Pb^{206}$ age sequence of U ores
210. Summary of hypotheses of genesis of U deposits
211. Th in the Powderhorn district, Gunnison County, Colorado
212. Geology and monazite content of the Goodrich quartzite Palmer area, Marquette County, Michigan
213. Importance of isotopes in technology and industry
214. Management and disposal of radioactive wastes
215. Achievement of radiation protection by legislation and other means
216. Insurance for reactor operations
217. Industrial training aspects of peaceful uses of atomic energy
218. Use of C^{14}-labeled compounds in tuberculosis research
219. Radiation effects on cells: Genetics or physiology?
220. Association of irradiation with cancer of the thyroid in children and adolescents
221. Reduction of mortality from whole-body X-irradiation in rabbits by pretreatment with antipyretics and bacterial vaccines
222. Permissible exposure to ionizing radiation
223. Is the concept of "critical organ" valid in determining the maximum permissible level for exposure to radioactive materials?
224. Effect of X-irradiation on fat metabolism
225. Modes of acute radiation death
226. Pathways of biosynthesis of nucleic acids
227. Nucleotide and nucleic acid metabolism studied with adenine-C^{14}
228. Nature of I^{131} compounds appearing in thyroid vein of horse and sheep after injection of iodide-I^{131}
229. Use of C^{14}-labeled amino acids in the study of protein synthesis
230. Some biochemical functions of the cell surface as deduced by isotope studies
231. Study of certain phases of cell dynamic states with short-lived isotopes as exemplified by Mn^{56} partition studies in organs and intracellular organelles
232. Metabolism of mucopolysaccharides
233. Meteorology and atomic energy
234. Nuclear energy and oceanology
235. Radioactivity in terrestrial animals near an atomic-energy site
236. Environmental aspects of the atomic-energy industry
237. Decontamination of radioactive water supplies
238. The Los Ocho uranium deposit
239. U in lignites of South Dakota
240. U-bearing coal in central part of Great Divide Basin, Sweetwater Co., Wyoming
241. U in asphalt-bearing rocks
242. U in phosphate rock
243. U in the Phosphoria formation
244. A comparison of black U ores in Utah, New Mexico and Wyoming
245. Paragenetic studies of U deposits of the Colorado Plateau
246. Isotope geology of some U minerals
247. Geology of Th deposits in U. S.
248. Mineralogy of Th
249. Th deposits in Wet Mountains, Col.
250. U- and Th-bearing minerals in placer deposits in Idaho
251. Monazite in southeastern U. S.
252. Radioisotopes in medicine
253. Method for decontamination of low-level radioactive liquid wastes
254. Disposal of low-level radioactive wastes
255. Preparation of kilocurie quantities of Xe^{133}
256. Large-scale production of radioisotopes
257. Methods of handling multikilocurie quantities of radioactive materials
258. Design of radiation analytical facilities at ORNL
259. Design and operation of a pilot plant to produce kilocurie fission-product sources
260. Preparation of kilocurie La^{140} sources
261. Administrative problems in radiation protection in New York State
262. Workmen's compensation aspects of peaceful uses of atomic energy
263. Capital investment required for nuclear energy
264. Physical dosimetry and clinical observances on four human beings involved in an accidental critical-assembly excursion
265. Assaying the function of total biotic communities in relation to the new field of radiation ecology
266. Experimental determination of the self-regulation and safety of operating water-moderated reactors: Results and motion-picture records
267. Environmental effects of a major reactor disaster
268. Radiological monitoring of a nuclear release
269. The Materials Testing Reactor—experimental program and operating experience
270. Operation, training and research experiences with the Raleigh research reactor
271. Design and description of water boiler reactors
272. "Swimming Pool"—A low cost reactor for research and medicine
273. A developmental fast-neutron breeder reactor
274. A graphite-moderated nuclear power plant design
275. Botanical methods of prospecting for U
276. Pressurized water reactor (PWR) water chemistry
277. The removal of fission products from stainless steel
278. The metallurgy of Th and its alloys
279. Problems of ground disposal of nuclear wastes
280. Pulsed accelerator slow-neutron velocity spectrometers
281. Time-of-flight instrumentation for neutron spectrometer
282. Uses of radioisotopes by the Hawaiian Sugar Plantations
283. Radioisotopes in industrial research
284. Progress and problems in the development of cold sterilization of foods
285. Basic studies relating to the use of ionizing radiations for meat processing
286. Research in the U. S. on the radiation sterilization of foods
287. The localization of eye tumors with P^{32}
288. Biosynthesis of abnormal proteins in multiple myeloma
289. The use of I^{131} labeled serum albumin in the study of cardiac output and peripheral vascular flow
290. Body composition in normal and abnormal states
291. Thyroid radioiodine uptake calibration
292. Pre-therapeutic considerations for 70-Mev X-rays
293. Biological studies on La, Y, Ca, and Sr
294. Studies on the state of thyroid hormone in the blood and its peripheral degradation
295. The effects on plants of chronic exposure to gamma radiation from Co^{60}
296. Alternate energy sources (unconventional types)
297. The role of energy and the role of nuclear energy in the U. S.
298. A century of growth of electric power requirements in the U. S.
299. Nuclear fuel for the world power program
300. Natural occurrence of U in the U. S.
301. U in terrestrial sedimentary rocks in the U. S. exclusive of the Colorado Plateau
302. U-Va-Cu deposits on the Colorado Plateau
303. Examples of U deposits in the Upper Jurassic Morrison Formation on the Colorado Plateau
304. A study of the economic potential of nuclear energy
305. Economics of nuclear power
306. Ra inhalation accident—Ra excretion study
307. The nuclear reactor in basic science
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309. The Materials Testing Reactor and related research reactors
310. A sodium-graphite-reactor 75,000-electrical-kilowatt power plant
311. Liquid-metal-fuel reactor
312. Boiling-water reactors for industrial power
313. Aqueous homogeneous power reactor
314. The engineering design of a prototype boiling-water-reactor power plant
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316. Los Alamos power-reactor experiments
317. Rock alteration criteria in the search for U
318. Geologic prospecting for U and Th
319. Heavy-mineral prospecting
320. Airborne radioactive surveys
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322. Scintillation drill-hole logging
323. Drilling technique in search of U
324. Geophysical exploration for U on the Colorado Plateau
325. Geophysical-geochemical prospecting for U
326. Subsurface techniques for outlining favorable zones by widely spaced core drilling
327. Techniques in exploration of shinarump type channels on the Colorado Plateau
328. Air scattering of gamma rays from thick U sources
329. Recovery of U from its ores
330. Alkaline leaching of U ores
331. Some unusual problems met in the recovery of U from a very low-grade ore
332. Recovery of U from sulfuric acid and carbonate leach liquors by anion exchange
333. Solvent extraction of U from acid leach slurries
334. Recovery of U from phosphates by solvent extraction
335. The carbonate chemistry of U: Theory and applications
336. The use of the resin-in-pulp process for recovery of U
337. A general survey of types and characteristics of ion exchange resins used in U recovery
338. Accelerated thickening and filtration of U leach pulps
339. Some factors in extracting U from low-grade ores
340. Production of Th metal
341. Fundamental considerations in the reduction processes for U and Th
342. Spectrophotometric determination of U with thiocyanate in acetone-ethyl acetate-water medium
343. Zr metal production
344. The production and properties of graphite for reactors
345. Aqueous corrosion of Al alloys at elevated temperatures
346. Aqueous corrosion of Zr and its alloys at elevated temperatures
347. Redox process—A solvent extraction reprocessing method for irradiated U
348. Solvent extraction separation of U and Pu from fission products
349. The solvent extraction separation of U^{233} and Th from fission products
350. The processing of U-Al reactor fuel elements
351. High-temperature fuel processing methods
352. A direct maintenance radiochemical processing plant
353. Pyrometallurgical processing of nuclear materials
354. The purification of U reactor fuel by liquid-metal extraction

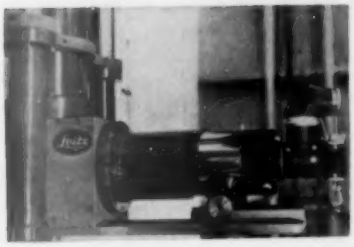
(Continued on page 134)

PRODUCTS AND MATERIALS

Radiohazard Signs

Printed in colors that conform to AEC and ASA specifications, warning signs (shown right) are available in 2¼ × 9, 3½ × 10, and 5 × 14 in. Signs are self-sticking, come on individual dispenser cards. Combinations can be assembled from separate signs.—W. H. Brady Co., 727 W. Glendale Ave., Milwaukee 12, Wis.

RADIOACTIVITY MATERIALS AND APPARATUS



Hot-Lab Periscope

Stereoscopic telescope-periscope built for KAPL provides closeup of radioactive specimens equal to 5× unaided eye at 10 in. Optical path length is 20 ft; object field is 45 mm in diameter. Leica-72 can replace binocular eyepiece for two-exposure-stereoscopic or ordinary photography as shown above.—E. Leitz, Inc., 486 Fourth Ave., New York, N. Y.

Gold Infusion Unit

Based on Lough's design (NU, Feb. '55, p. 62), new cart-mounted unit administers 150–250-mc colloidal Au^{198} sterilely and safely directly from ORNL 10-ml shipping bottle. Technician's dose is below 5–10 mr.—William B. Johnson, Inc., Empire State Building, New York 1, N. Y.

•

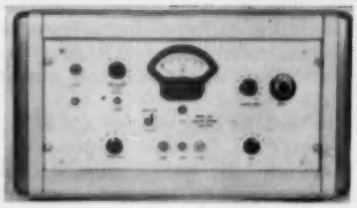
I^{192} radiography unit. Sources up to 75 c can be exposed from 50 ft away using flexible-cable principle of the Isotron.—The Gamma Corp., Mansfield, Mass.

Radiographic-exposure calculator. Slide-rule-type calculator determines Ra or Co^{60} exposure times on basis of film type, source-film distance, photographic density required, source strength, and thickness of steel specimen. Radiation shielding requirements are also given.—Technical Operations, Inc., 6 Schouler Court, Arlington 74, Mass.

Isotope carrier. Model L-7 has 1-in.-lead shielding throughout, rubber carrying handle, lock, and 1½-in.-diameter × 4-in.-deep storage hole.—NRD Instrument Co., 6429 Etzel Ave., St. Louis 14, Mo.

Neutron film badges. Weekly service provides nuclear track emulsions for proton-recoil determination of neutron exposure.—R. S. Landauer, P. O. Box 102, Park Forest, Ill.

RADIATION DETECTORS AND ACCESSORIES



Medical Spectrometer

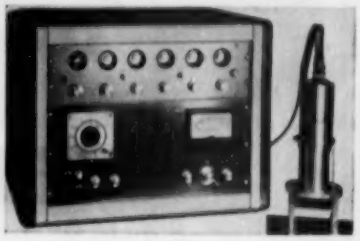
Model DZ21 (above), based on the Francis-Bell circuit, combines high-voltage supply, linear amplifier, single-channel pulse-height analyzer, and count-rate meter. Model DP21 scintillation probe available.—Detectolab, Inc., 6544 N. Sheridan Rd., Chicago 26, Ill.

Tissue-Equivalent Materials

The conductive plastic and the special gas formulations described next are used in the construction of tissue-equivalent chambers.

• CP-705 is available with a weight composition of 9.0–10.2% hydrogen, 0.5–4.0% nitrogen, with the balance carbon. Material is uniform and stable, has low permeability. Data on compression and injection molding are available.—F. A. Muller, Federal Telecommunication Laboratories, 500 Washington Ave., Nutley 10, N. J.

• Gases of all compositions, including tissue-equivalent mixtures are available in standard small cylinders.—A. Mossman, Mathesson Co., E. Rutherford, N. J.



Scaler, Glow-Tube Register

Featuring interchangeable binary or decimal scales, the model 200 scaler is shown above with GT-6 preset glow-transfer-tube register that can be preset to any count from 10 to 10^9. Unit includes gain-of-2,500 linear amplifier with 1-mv input sensitivity, 500–5,000-volt high-voltage supply, internal mercury-relay pulser, and built-in automatic timer.—Radiation Instrument Development Laboratory, 2337 W. 67 St., Chicago 36, Ill.

X-Ray Counters

These two counters were designed for use with X-ray diffraction equipment:

Products Index

Radioactivity Materials and Apparatus 129
Radiation Detectors and Accessories 129
Laboratory Instruments and Apparatus 131
Industry Notes 132
Literature Available 133

NEW

RAPID GERMANIUM D.C. POWER SUPPLIES

WITH

95% Efficiency

95% Efficiency at full load is standard with the new RAPID GERMANIUM RECTIFIERS. What's more, voltage is stabilized to ± 1 volt from no load to full load. And, these are just two of the many advantages of these new units.

With continuously variable, oil immersed inductor controls, RAPID GERMANIUM RECTIFIERS are the power supplies of tomorrow—here today. Write for complete information, today. Write to Rapid Electric Co., 2881 Middletown Road, New York 61, N. Y. Ask for Bulletin

THE NAME THAT MEANS *"More Power to You!"*

RAPID ELECTRIC COMPANY

1.4 times more gamma-ray attenuation than lead . . .

Carboloy Hevimet reduces shield size and weight

Nominal Properties of Hevimet

Mechanical Properties:

Tensile Strength (p.s.i.)	95,000 Min.
Hardness (Rockwell "C")	20—30
Modulus of Elasticity (p.s.i.)	50 x 10^6
Modulus of Rupture (p.s.i.)	200,000
Yield Strength (0.2% offset) (p.s.i.)	75,000
Elongation (% in 2 inches)	2% Min.
Proportional Elastic Limit (p.s.i.)	27,000

Thermal Properties:

Coefficient of Thermal Expansion (in./in./°C) (20°-400°C)	5.6 x 10^{-6}

Electrical Properties:

Electrical Conductivity	15.4% I.A.C.S.
Magnetic Permeability	non-magnetic

Shielding Properties:

X-Ray Absorption @ 2,000,000 volts	1.4 x lead
Half-Value Layer for Co^{60} (inches) (narrow beam)	0.330
(broad beam)	0.344

Carboloy® Hevimet makes a more effective gamma- or X-ray shield – with less bulk – than lead. This tungsten-nickel-copper alloy is an ideal material for shielding applications where size and weight are critical.

With its high density (16.9-17.2 gms/cm^3), Hevimet combines excellent physical and electrical properties. It is easily machined or drilled to close tolerances; easily polished or plated.

Hevimet blanks are available in rough, semi-finished, or finished form. For complete technical information, send for Bulletin HV-4.

"Carboloy" is the trademark for products of the Carboloy Department of General Electric Company

CARBOLOY

DEPARTMENT OF GENERAL ELECTRIC COMPANY

11130 E. 8 Mile Ave., Detroit 32, Michigan

CARBOLOY CREATED-METALS FOR INDUSTRIAL PROGRESS

(1) 6-in.-long, 1⅞-in.-diameter, 9-oz scintillation counter-preamplifier unit with 1-μsec resolving time, 45-cpm background, 600–800-volt threshold, and 75-volt-minimum plateau. (2) 4½-in.-long, 1-in.-diameter, 4-oz. proportional counter-preamplifier unit with 1-μsec resolving time, 20–30-cpm background, 1.4-mg/cm^2 mica window 5/16 × ⅜ in.—North American Philips Co., 750 S. Fulton Ave., Mt. Vernon, N. Y.

Prospecting Counters

Here are five new additions to the growing group of instruments designed for uranium prospecting.

- Model 2613, the Oracle, has 10 Geiger tubes for 0.001-mr/hr sensitivity. Battery life is 250 hr continuous, or equal to shelf life for 2-hr/day operation. Comes with meter, earphones, and 0.1%-U sample.—Nuclear Chicago, 229 W. Erie St., Chicago 10, Ill.
- Weighing just 4¾ lb, model GS-3 has large Geiger tube on probe cable.—Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Indiana.
- Model 111-B Percentometer can register percentage of U for field radioassay. Scintillation crystal (1½ in. in diameter) and 3-in. meter make for high sensitivity.—Radiac Co., 489 Fifth Ave., New York 17, N. Y.
- Featuring a 1-flashlight-battery supply, S101 Geiger Gun has meter and headphone outputs.—Scientific Radio Products, Inc., 215 S. 11 St., Omaha 8, Nebraska.
- Transistorized model B Geiger counter weighs but 1 lb, operates 100 hr on single mercury battery, has earphone output only.—Transimite Laboratory, Manteo, North Carolina.

•

31-kv d-c supply. Model S6-105 is oil-filled and has 10-milliamp output, negative ground. Other ratings available.—Central Transformer Co., 910 W. Jackson Blvd., Chicago 7, Ill.

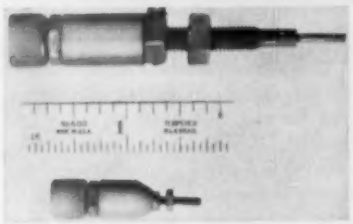
Pulse generator. Repetition rates from 10 to 10^5 cps, pulse widths from 0.1 to 1,000 μsec, variable 93-ohm output (to 40 volts), five synchronizing pulses: these are features of B2A pulse generator.—Rutherford Electronics Co., 3707 S. Robertson Blvd. Culver City, Calif.

Scintillation counter. In model D4105, sample is contained in 25-ml alkathone vessel, activity is measured by NaI(Tl) crystal and 11-stage

photomultiplier. Glow-transfer counter chronograph and instrument for measuring ratio of three pulse rates are also available.—Labgear (Cambridge) Ltd., Willow Place, Cambridge, England.

Large stop-clock. Having 48-hr spring, Durachron stop-clock reads elapsed minutes and seconds with 0.016% accuracy on 4 or 8-in. dial.—Andrew Technical Service, 6972 N. Clark St., Chicago 26, Ill.

LABORATORY INSTRUMENTS AND APPARATUS



Small Thermocouples

For installation in walls, two thermocouples (above) are available. Junction is formed by nickel plate on end of steel tube. Probe diameter is 0.09 in. for model 1, for model 2 probe is threaded (2–56), about 0.1 in. diameter. Temperature ranges are −300–800° F and −300–2,000° F. Very fast response is achieved.—Midwest Research Institute, 4049 Pennsylvania, Kansas City 11, Mo.

Accurate Thermocouple

Fiberglass-insulated, stainless-steel, two-wire thermocouple has accuracy of 5° F from 0–1,000° F. Element is of 20-gage wire. Greater flexibility is possible than with ceramic-insulated models. Lengths are from 6–60 in.—Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves, Philadelphia 44, Pa.

New Chemicals

Additions to a line of rare-earth oxides and a reagent grade chemical for Zr and Hf analysis have been announced.

• Newly available chemicals, and some old products at lower prices are: thulium oxide-99% minimum purity; lutetium oxide, 99%; ytterbium oxide, 99.8 and 99%; and europium oxide, 99.8%.—Research Chemicals, Inc., P. O. Box 431, Burbank, Calif.

• Reagent grade *p*-bromomandelic acid has been successfully used for

REGULATED HIGH VOLTAGE POWER SUPPLY

MODEL N-401 450–1800 Volts Positive Continuously Variable 0-5 MA

INTRODUCING the Model N-401 regulated high voltage power supply using the new ultra stable 85A2 voltage reference tube under constant current operation.

SPECIAL FEATURES

- STABILITY against line voltage changes 3 PPM†/volt in the range 105–125 volts.
- REGULATION — — — 2.5 PPM/ma in the range 0–5 ma.
- OUTPUT IMPEDANCE—approximately 2.5 ohms shunted by 0.5 mfd.; provides low hum pick-up.
- LOAD TRANSIENT RECOVERY time constant 80 microseconds, no load to full load.
- TEMPERATURE COEFFICIENT −100 PPM/°C.
- LONG TERM STABILITY limited entirely by the voltage reference tubes at less than 10 PPM/hour for the first 1000 hours of life and less than 2 PPM/hour thereafter.
- NOISE AND RIPPLE less than 3 PPM peak-to-peak.
- QUALITY components, hermetically sealed high voltage transformer, 4 inch panel meter, high resolution fine control.

† PPM = parts per million at 1000 volts.

USES

- HIGH RESOLUTION scintillation spectroscopy.
- HIGH MULTIPLICATION proportional counters.
- PULSED COUNTER work requiring high surge currents.
- GENERAL APPLICATIONS requiring battery like stability.

Immediate delivery from stock...F.O.B. Princeton, N. J....$428.00

Write for Brochure

HAMNER ELECTRONICS CO., INC.

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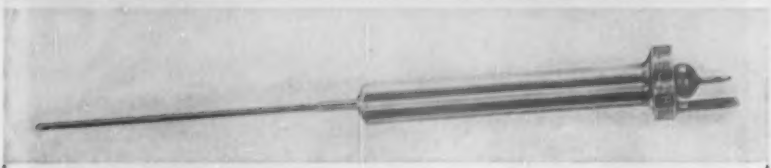


LELAB GEIGER-MUELLER TYPE COUNTER TUBES

Metal-Walled—Resist Shock

Except for a glass bead insulator, Lelab counter tubes are constructed entirely of metal. The metal cylinder is used both as the envelope and cathode of the tube—providing it with strength, resistance to shock and simplicity of design.

The restriction of all component parts within the diameter of the tube permits the close stacking of many tubes within a confined space. Each counter is custom-built, filled and tested in order to insure stability and reproducible results.

LELAB PROBE COUNTER TUBE FOR NEUROSURGERY

(Robinson-Selverstone Type)

Made especially for neurological surgery and other purposes requiring a miniature probe tube. The small needle-like probe provides an ideal way of measuring radioactivity *in vivo* and for probing small areas with a relatively strong field intensity.

Write Dept. B for complete information

H. W. LEIGHTON LABORATORIES, 26 Herman St., Glen Ridge, N. J.

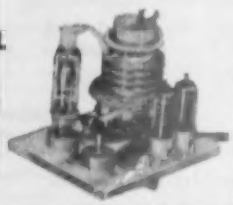
SPELLMAN HIGH VOLTAGE POWER SUPPLIES

MODEL LAB—60 RF TYPE CONTINUOUSLY VARIABLE 0-60 KV DC REGULATED POWER SUPPLY

Current output 1 ma. at 60 KV. 2 ma. may be drawn from 50 KV to 0. Supplied with either positive polarity or negative polarity output.

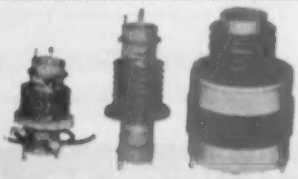
LAB-60 Complete with meter.....$695 Net
LAB-60 PN Reversible polarity model of above.....$745 Net

MODEL 4575 4½ KV POWER SUPPLY



This compact, well designed, ruggedly built DC supply utilizes two 6AQ5 tubes as a parallel oscillator feeding a 1X2 rectifier tube. For an output voltage of 4½ KV DC at 1 milliampere, the low voltage input requirement is 250 V at 50 milliamperes. By varying the DC input the output voltage can be varied from approx. 1 KV to 7½ KV. Dimensions: 5⅝" high × 5" deep × 4¼" wide. In completely enclosed metal housing (not shown). Less low voltage DC supply $32.50 Net

HIGH VOLTAGE STEP-UP COILS



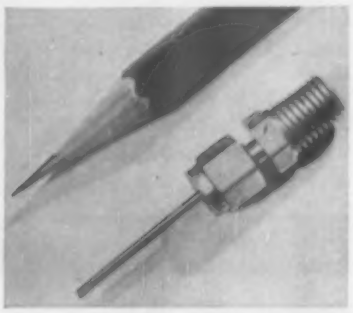
5 KV . . $4.80 Net
10-15 KV . . 12.00 Net
25 KV . . 36.00 Net
35 KV . . 42.00 Net

SEND FOR COMPLETE INFORMATION

SPELLMAN TELEVISION CO., INC.

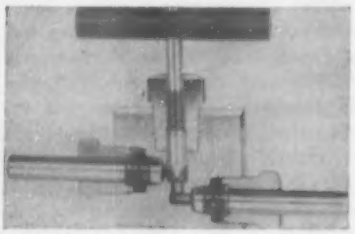
3029 WEBSTER AVENUE
N. Y. 67, N. Y.
Kingsbridge 7-0306

Zr and Hf analyses. It is claimed superior to other reagents. Melting point of the compound offered is 116–117.5° C.—Pilot Chemicals, Inc., 47 Felton St., Waltham 54, Mass.



Capillary-Tube Fitting

By slipping $\frac{1}{16}$ in. tubing into fitting and turning nut until tight seal is secured, the Swagelog tube fitting (above) is ready for installation. No flaring is needed. Fitting is made in brass, aluminum, steel, stainless steel and Monel.—Crawford Fitting Co., 884 E. 140th St., Cleveland 10, Ohio.



Tubing Valve

Pipe threading is not necessary when installing the TubeLine valve. Tubing is cut and connected to valve with adaptor nut and sleeve as shown above. Gas-tight seal is formed. Valve body is 304 stainless, stem is 410. Valve pressure rating is 4,000 psi. Tubing from $\frac{1}{8}$–$\frac{1}{2}$-in. o. d. can be used.—Autoclave Engineers, Inc., 879 E. 19th St., Erie, Pa.

INDUSTRY NOTES

▶**Hycon-Eastern Inc.,** Cambridge, Mass., has been formed to develop and manufacture products for nuclear instrumentation and control, and other fields. **M. M. Hubbard** is president; directors include **J. R. Zacharias** and **J. B. Wiesner** of MIT. **Hycon Mfg. Co.** is the majority stockholder.

▶**Standard Electronics Division, Hupp Corp.,** Carlisle, Pa., is the new

name of the **Standard Piezo Co.**, following a merger. Products include a CdS-crystal radiation meter.

▶**Beckman Instruments Inc.**, Fullerton, Calif., has completed a contract for 100 mass spectrometers for U^{235} gaseous-diffusion-plant quality control. Delivery was nearly a year ahead of schedule.

▶**Universal Atomics Corp.**, New York, N. Y., plans to manufacture and market transistorized, printed-circuit radiation-detection instruments. Firm now distributes radiation counters. **J. A. Gannon, Jr.**, is president of the new firm.

LITERATURE AVAILABLE

Atomic-industry products. Bulletin 274 presents typical products in atomic-energy line, such as radiation shielding, reactor components, storage casks and remote-controlled manipulators. 18 p.—Farrel-Birmingham Co., Ansonia, Conn.

Industrial process tracers. Bulletin IT-103 describes 14 radiotracers, both solid and liquid. 28 p.—Tracerlab, Inc., 130 High St., Boston 10, Mass.

Radiation instruments. Catalog illustrates and describes such radiation instruments as: liquid-phosphor counters, scalers, linear amplifiers, ratemeters, power supplies, scintillation detectors and crystals. 20 p.—Technical Measurement Corp., 140 State St., New Haven 11, Conn.

Counters and controllers. Data sheets are available on line of counters and controllers, including both totalizers and pre-set units. 4 p.—Atomic Instrument Co., 84 Massachusetts Ave., Cambridge 39, Mass.

Computation facilities. Brochure describes the computational facilities and code library available for problems such as network analysis and heat-transfer calculations. 16 p.—Midwest Research Institute, 425 Volker Blvd., Kansas City, Mo.

Precious-metal plating. Booklet lists properties of precious-metal electrodeposits. Harper Leader Inc., Waterbury 20, Conn.

Electron microscope. Brochure 3R2546 tells principles and uses of electron microscopes.—Scientific Instruments, 15-1, RCA, Camden, N. J.

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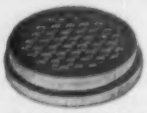

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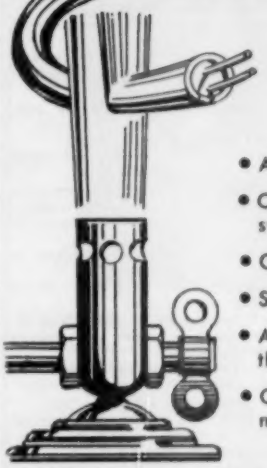

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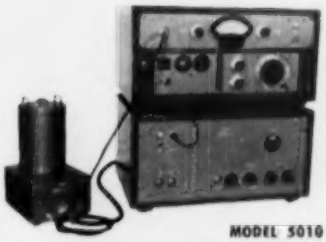

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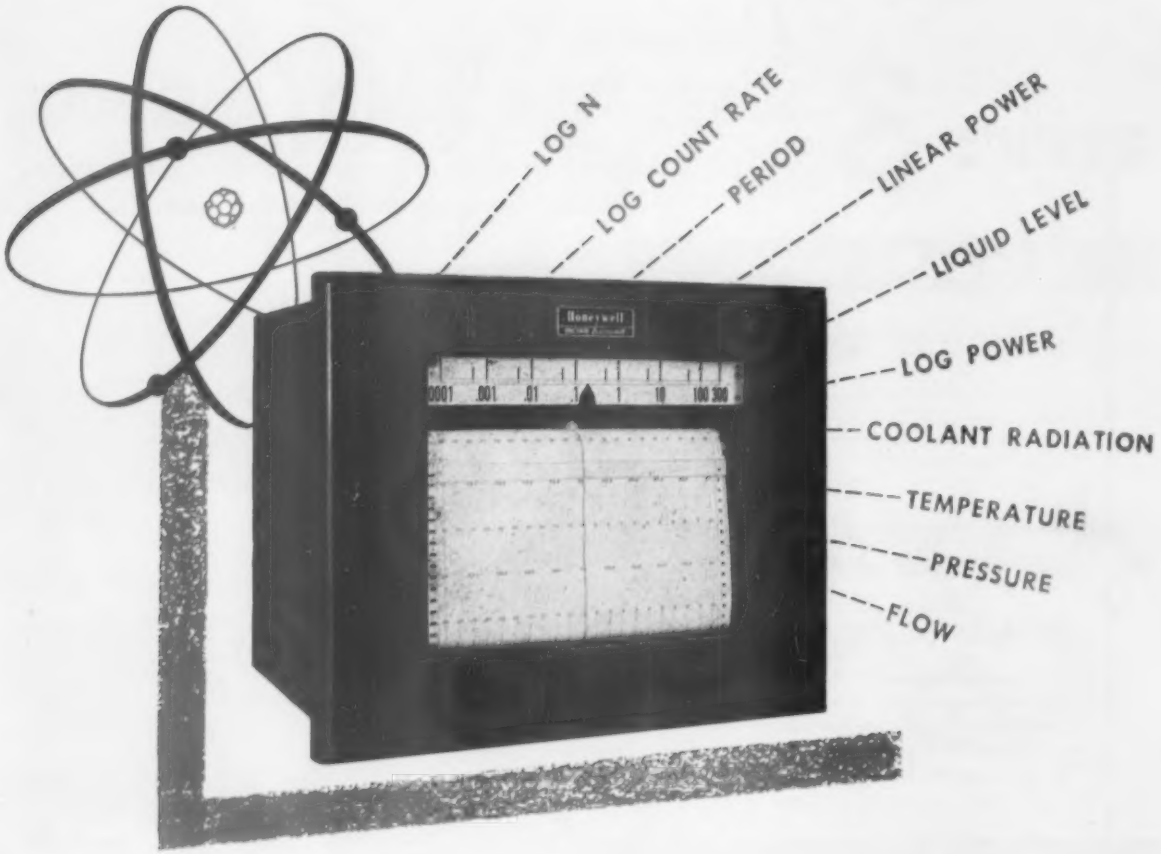

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